Instruments THE MAGAZINE OF Measurement and Control

M. F. BEHAR, Editor

"Rich Variety" or Chaotic Anarchy?

". . . the current American pedagogical theory, fostered by professional Schools of Education, that the less a man knows about what he is to teach the better he will teach it . . ."—Professor ERIC TEMPLE BELL

VARIETY may be "the very spice of life, that gives it all its flavor"—but this immortal line (by Cowper whose respect for rules of measured verbal rhythmic order shone in ev'ry syllable) itself exemplifies the paradox of words whose structure demonstrates almost the opposite of what they say. . . . These unrimed iambi mean that there has to be an *orderly* slice of life that can be improved by variety's spicing. In the case of such a slice of life as technical education, the meat itself must be composed of standard elements. This is true in all grades of technical education from the training of apprentices to the supervision of doctorate-aspirants. It is true in all branches.

Sixteen courses labeled "Industrial Instrumentation" were included in college and university curricula in the last academic year. Are they balanced diets with certified meat as the foundation? Probably, because the faculties would not stoop to the false-label practices of patent-medicine gyps. Moreover, the S.P.E.E. strives to make engineering schools serve more certified meat and fewer spices. But the millenium isn't here. Professor Estep (see page 225) implies that too many candidates for the M.E. degree who want to learn what goes on in a machine are merely made to conduct "cold tests" suited to schoolboy mentality. This probably can be said of the majority of institutional courses on the functioning of automatic controllers. And I do say it! What emboldens me to say it is the inspiring A.I.E.E. address* by Doctor C. A. Adams in which he declares:

Why is it so easy to bamboozle the majority of people by a propaganda of lies? Only because their education is so superficial. . . . Their minds are crammed with a mass of information, mostly uncoordinated. In some cases, as in our engineering colleges, they are even carefully trained in what purports to be sound quantitative logic, but which is actually so crudely superficial that in most cases they know absolutely nothing about the approximations involved or the variables neglected. They think they are getting sound theory when in fact they are getting only the superficial technique of a trade and are absolutely helpless in the case of a new type of problem, or even of an old type of problem a little outside of the conventional range. They learn how to push the buttons and turn the cranks, and usually without any real understanding of what it is all about. In short, they are taught to do everything but think for themselves.

It is not enough to have automatic controllers on view and to include "the thermostat experiment," "the governor experiment" and "the voltage-regulator experiment" (these being like the "cold tests" against which Professor Estep protests). Each controller-and-application setup must be supplemented by as many instruments as are used in a boiler-and-turbine test! To learn the behavior of a modern temperature controller, for example, you must use more instruments than are used in testing a modern airplane engine! As far as I know, only M.I.T. and California have nearly enough equipment and allot nearly enough hours. As far as I know, even these two admirable public institutions serve less fundamental meat on Control Technology than is served privately by some instrument companies (notably L&N and Foxboro) behind jealously-guarded doors.

It all comes down to the fact that Industrial Instrumentation is still a *new* branch of engineering education, hence unstandardized. At present, the variety of measurement and control courses *almost amounts to utter chaos*. And in making this assertion I don't have to be bold: the facts speak for themselves. Here are the facts, in the form of two lists of "labels" patiently compiled by Mr. Rimbach, president of the Instruments Publishing Co., from the catalogs of colleges and universities: —MFB

Electrical Engineering, Vol. 60, Aug. 1941, pages 371-373.

REGULAR COURSES (Acad. yr. 1940-41)

No. of Institutions (catalogs) 179
No. of Different Courses..... 37
Total No. of Courses..... 631

Electrical Measurements	81
Mechanical Laboratory	54
Hydraulics (Flow of Liquids)	54
Temperature & Pyrometry	34
Electronics	29
Microscopy	27
Testing Materials & Physical Testing	25
Spectroscopy	22
Optics & Light	21
Gas, Oil & Fuel Analysis	21
Motion & Time Study	19
High-frequency Measurements	17
Industrial Instrumentation	16
Aircraft Instruments	14
Physical Measurements	6
X-Rays	5
Meteorology	5
Metrology (Gages & Gaging)	4
Glass Blowing	4
Textile Testing	3
Physico-Chemical Measurements	3
Gas Measurements	3
Navigation	3
Hydrogen Ion Concentration	2
Paper Testing & Analysis	2
Internal Combustion Engine Testing	2
Photomicrography	2
Instrumental Analysis	2
Vibration	2
Magnetic Measurements	2
Optics Applied to Instruments	1
Optical Instruments	1
Instrument Making	1
Oil Field Testing Methods	1
Color Measurements	1
Servo Mechanisms	1
Theory of Engineering Instruments	1

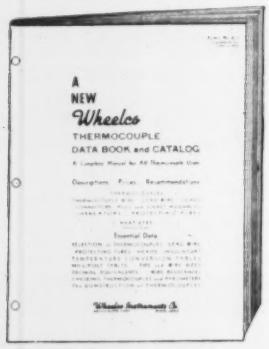
DEFENSE COURSES (Acad. yr. 1940-41)

No. of Institutions (catalogs) 61
No. of Different Courses..... 53
Total No. of Courses..... 177

Materials Inspection & Testing	61
Electronics & Radio	16
Time & Motion Study	14
Instrumentation	6
Concrete Inspection & Testing	6
Testing of Chemicals	5
Aircraft Inspection	5
Transit Surveying & Mapping	5
Electrical Measuring Instruments	4
Optics & Optical Engineering	4
Textile Testing	3
Ordnance Inspectors Course	2
Shop Processes, Mathematics & Measurement	2
Internal Combustion Engine Testing	2
Chemical Analysis of Metallurgical Materials	2
Air Navigation	2
Operation Inspection or Inspection Problems	2
Metallography	2
Design of Tools & Testing Equipment	1
Explosives Inspection	1
Radio Testing & Inspection	1
Dynamic Analysis of Servomechanisms	1
Food Inspection	1
Instrument Men & Topographers	1
Non-Metal Material Inspection	1
Inspection & Metallurgical Technician Training	1
Process & Finish Material Inspection (Women)	1
Principles & Practices of X-Rays	1
Electrical Circuit Theory, Machines & Instruments	1
Chemical Testing (Plastics)	1
Fluid Control Mechanisms	1
Instrument Design	1
Inspection of Instruments	1
Inspection of Electrical Instruments	1
Inspection of Welded Products	1
Inspection of Materials of Chemistry	1
Inspection of Construction Materials	1
Inspection of Steel & Cast Iron	1
Petroleum Refinery Control	1
Pyrometry	1
Machinery Inspection & Testing	1
Metallurgical Inspection	1
Spectroscopic Testing of Materials	1
X-ray Testing of Materials	1
Chemical & Industrial Materials Inspection	1
Inspection of Petroleum Products	1
Meteorology	1
Radiography of Metals	1
Inspection Gage Design	1
Automatic Electrochemical Control	1
Aerial Mapping & Surveying	1
Inspection & Use of Gages	1
Aircraft Instruments	1

NEW! — COMPLETE!

THERMOCOUPLE
DATA BOOK and CATALOG



Every thermocouple user needs a copy of this new Wheelco Bulletin. It not only contains prices and descriptions of our complete line of thermocouples and thermocouple accessories but, in addition, gives recommendations for their selection and use. Essential data—the making of thermocouples, temperature conversion and millivoltage tables, wire resistances, etc.—are also included.

You can select and order the thermocouple you need, directly from this book.

FREE—upon request. Ask for Bulletin S2-3

Wheelco Instruments Co.
HARRISON AND PEORIA STREETS · · · CHICAGO, ILLINOIS

IMPROVED "SPOTLIGHTS"

Rubicon MULTIPLE REFLECTION galvanometers have recently been much improved through redesign of optical system. The definition of the line-image is now so sharp that readings can be estimated to .1 of a millimeter division.

These sturdy self-contained galvanometers are available with sensitivities as high as 5×10^{-10} ampere and 1×10^{-6} volt per millimeter division.

ASK FOR BULLETIN 320

RUBICON COMPANY
Electrical Instrument Makers
Ridge Ave. at 35th St. Philadelphia, Pa.

Galvanometers, Electrometers, Potentiometers, Colorimeters, Wheatstone & Kelvin Bridges, Resistance Standards, Resistance Boxes, Coil Testers, Clip-on Ammeters, etc.

THE MONTH'S NEW INSTRUMENTS

In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control.

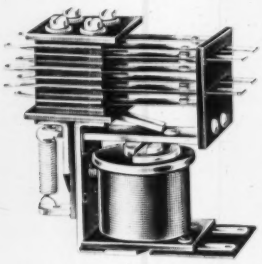
When writing to manufacturers directly, please mention this department as your source of information. Or write to Information Section, Instruments Publishing Company.

"One-inch-per-day" Inkless Portable Recorder

New low-chart-speed recorder telescopes 30-day load and voltage surveys formerly requiring 60-ft. strip charts into a chart only 30" long. An addition to maker's "Type CF" line of inkless recorders, its chart speed is 1" per day. This low chart speed is made possible by the inkless recording mechanism which makes an impression by pressing the chart against a typewriter ribbon. There being no freezing and evaporating of ink in extreme temperatures, the recorder will function accurately in temperatures ranging from —10° F. to 120° F. It is obtainable as an ammeter or a voltmeter.—*General Electric Co. Schenectady, N. Y.*

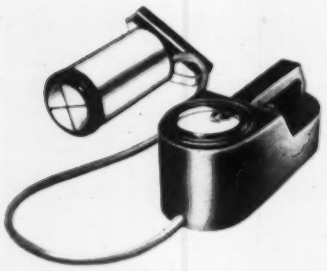
A-c. or D-c. Relay

New "Type F" Relay is available with 1, 2, 3 or 4 poles; single- or double-throw, to operate on a.c. or d.c. Contacts are said to have self-cleaning wiping action with heavy contact pressure. Dimensions: $2\frac{1}{4}$" high, $2\frac{1}{2}$" long and $1\frac{1}{8}$" wide. Underwriters clearances can be supplied.—*G-M Labs., 1731 Belmont Ave., Chicago, Ill.*



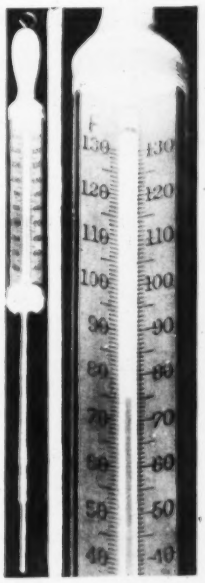
Moisture Meter

Feature of new model of Moisture Register, an instrument for testing moisture content of lumber, is a plastic and chrome-plated metal housing, replacing aluminum castings in view of defense needs. Result is improved lightness, portability and durability. Instrument determines moisture content in percentage by means of electrode contact, giving instantaneous dial reading. It is applicable to all types of woods. New model, ready for use, weighs 5 lbs.—*Moisture Register Company, 5117 Kinsie Street, Los Angeles, California.*



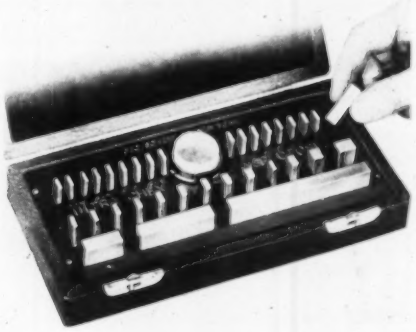
Sanitary Thermometer

New "Type T110 Clear Sight Sanitary Thermometer" is of radically novel design and construction. Use of molded plastics has made possible both a "cornerless" sanitary design and "crackless" construction whereby the stainless steel stem and the transparent plastic scale-case are joined without sharp edges or recesses. The same smooth exterior surface continues at the union of scale-case to handle. Entire instrument is waterproof and can be fully immersed in water when being washed. Glass mercury tube ("red-reading mercury" type) and scale being fully enclosed in plastic, there is no danger of glass particles or mercury droplets getting in food products in event of thermometer being dropped. Stem length $10\frac{1}{2}$"; scale length 7"; overall length 24".—*L. V. Edwards, 23 Irving Place, Rockville Centre, L. I., N. Y.*

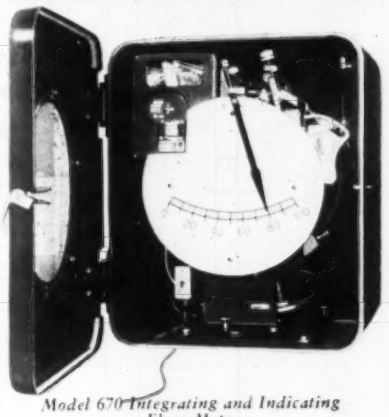


Gage Blocks and Optical Flat Combination

New "Ultra-Chex Inspectoset" consists of 34 gage blocks which will make up about 80,000 combinations in steps of 0.0001" from 0.300" to 8". An optical flat is also furnished with the new outfit.—*George Scherr Co., 128 Lafayette St., New York City.*



FLOW METERS FOR ALL PURPOSES



Model 670 Integrating and Indicating Flow Meter

★

HIGH PRESSURE METERS
Standard Differential Range—20" to 150" Water

LOW PRESSURE METERS
Standard Differential Range—1" to 8" of Water

★

Range Change Can be Made Without Taking Meter Out of Service

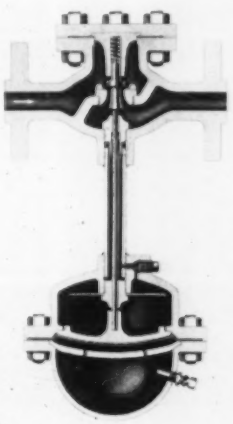
★

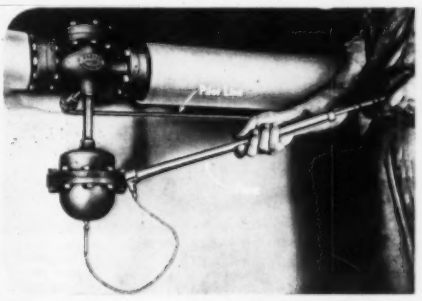
Write for Bulletin 410

RING BALANCE INSTRUMENT CO.
740 N. FRANKLIN ST. CHICAGO, ILL.

Pressure-reducing Regulators

New "Type 39-Q1" (single-seated) and "Type 39-Q2" (double-seated) pressure-reducing regulators for steam, hot liquids and hot gases, are for initial pressures up to 2500 lbs./in.², delivery pressures up to 1200 lbs./in.² and temperatures up to 1000°F. They will handle pressure reductions of magnitudes said to be "previously impractical in a single stage." They can be adjusted for reduced pressures from 5 lbs. to within a few pounds of the initial pressure by changing the dome load. Distinctive feature is adjustment of dome load. There are no operating springs, no stuffing box, no weights: instead, constant loading is imposed by air in dome. Lower illustration shows a dome being loaded by means of a hand pump; this may be



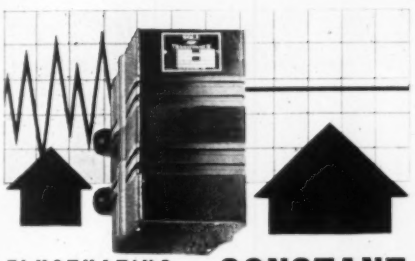


done also by means of a compressed-air line or of a charged bottle. Unloading is accomplished as in deflating an automobile tire, by pressing the valve in. Available sizes: ½" to 4".—*Foster Engineering Co., 109 Monroe St., Newark, N. J.*

Angle Form Direction Indicator

New form of the Kollsman Direction Indicator, with the dial on a 15° angle, is intended for mounting at the lower part of the instrument panel. Need for this angle

model appeared recently when the Navy found it necessary to move the compass from its regular place atop the instrument panel. Commercially, the new Direction Indicator may meet a similar need when circumstances will not permit mounting the compass in its regular place.—*Kollsman Instrument Div. of Square D Co., 80-08 45th Ave., Elmhurst, L. I., N. Y.*



FLUCTUATING LINE VOLTAGE **CONSTANT VOLTAGE**

Whether it's 1 VA for an instrument or 10 KVA for a Production line—here's constant, stable voltage for you at all times, even though the line voltage varies *as much as thirty percent.*

They are fully automatic and instantaneous in operation—have no moving parts—require no maintenance—and are self-protecting against short circuit.

You can build a SOLA CONSTANT VOLTAGE TRANSFORMER into your product, or incorporate it in your production line or laboratory and know that every test will be made under identical line conditions.

Compact—economical. Standard designs are available, or units can be built to your special specifications. *Ask for* **Bulletin GCV-74**

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BAILEY METER CONTROL SYSTEM

The Mark of
Effective Control

Process Control for sensitive, stable automatic control of temperature, pressure, liquid level, flow and other factors as applied to industrial processes. Responds to changes quickly, without overtravel or hunting. Ask for Bulletin No. 101.

Combustion Control that is simple but *complete* for providing economical operation of boilers of 200 h. p. and larger. Details in Bulletin No. 102.

Recorder-Controller

Boiler Meters for recording combustion conditions and guiding boiler operators. Described in Bulletin No. 44.

Multi-Pointer Gages for indicating factors such as draft, pressure, temperature and speed. These Gages are available with any number of pointers and any scale combination; in either the oil sealed bell or diaphragm construction.

Control Drive

Flow Meters for indicating, recording and integrating the flow of steam, water, sewage, air, gas and other fluids. Bulletins No. 39 and 300.

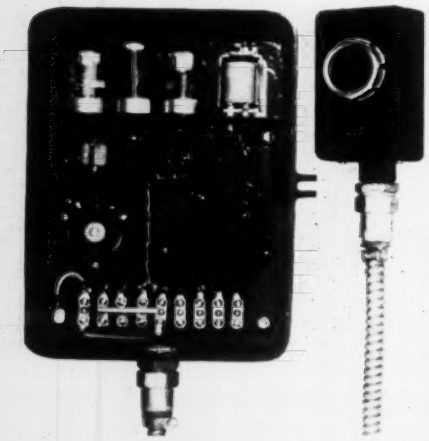
Recorders for pressure, temperature, drafts, liquid level and other factors.

G-3

BAILEY METER COMPANY
1041 Ivanhoe Rd., Cleveland, Ohio

Photoelectric Inspection and Register Control

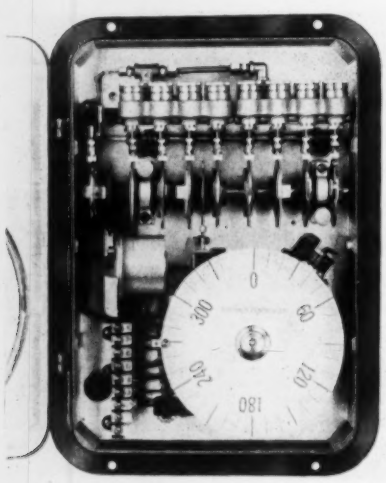
New "Type A80 Photoelectric Inspection and Registration Control" is a simplified system for controlling or inspecting cutting and printing operations on cellophane, paper,



cloth, foil, etc. It observes registration marks from penetration of light through transparent and translucent materials as well as reflection from opaque materials. An impulse of 0.001 sec. duration will initiate a controlling operation. Upon receiving an impulse, the control relay operates and remains in operation until the controlled circuit has completed its function, at which time the unit is reset automatically. It is used also for detecting presence and absence of labels on cans and the proper location of labels on goods, and other similar applications. All amplifying tubes are standard vacuum type. — *Photoswitch Inc., Cambridge, Mass.*

Time Cycle Controller

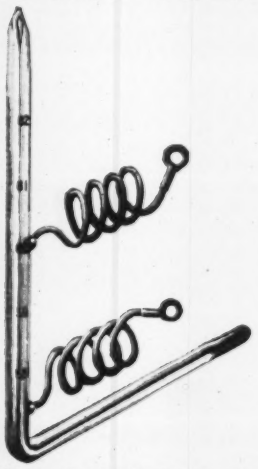
New multiple-cam "Model A-118 Impulse-Sequence Cycle Controller" is designed for use on tire molds and other plant processes where a number of factors must be timed



according to a fixed program. In operation it actuates or engages, at predetermined times in each cycle, the necessary mechanical, electrical, or pneumatic devices for automatically carrying out the intended schedule. Time measurement and pilot valve operation are handled by separate mechanisms. This timing is accomplished by a Telechron-driven aluminum disk, 8" in diameter, with a time scale printed on its periphery. A schedule of operations is incorporated into the disk by punching holes with an ordinary ticket punch on the time scale. Disks for new cycles or schedules of operation can be easily made. The cams are individually adjustable and their setting does not require fine adjustment in order to get accurate results. Any sequence of operation can be obtained. All controllers are drilled for eight cams and pilot valves. Additional cams and pilot valves up to a total of eight can be added by the user to controllers originally made up with less than eight cams.—*The Bristol Co., Waterbury, Conn.*

For Extremely Close Temperature Control

Visual-Stats



● Sensitivity of a hundredth of a degree is easily attainable. ● Top of mercury column visible at control point (where most important) because electrodes terminate at back of tube. No encircling metal bands! ● Available in angle form (illustrated) or conventional straight form. ● Send for brief, attractive bulletin.

The Philadelphia Thermometer Co.
915 Filbert Street -:- Philadelphia

Oldest Thermometer Manufacturer in Philadelphia

Speed - - -

DIRECT READING INDICATORS

Centrifugal Type

Portable and Stationary
Indicating Speed and Total Run.
Flexible Shaft, Belt, or Electric
Drives for Remote Indicating.

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Types Available for Every Industry

Locomotives, Steam, Gas,
and Electric. Baking Time for Ovens,
Dryers, Etc.
Centrifuges, Textile Machinery
Marine, Fire Apparatus
Automotive, General Machinery

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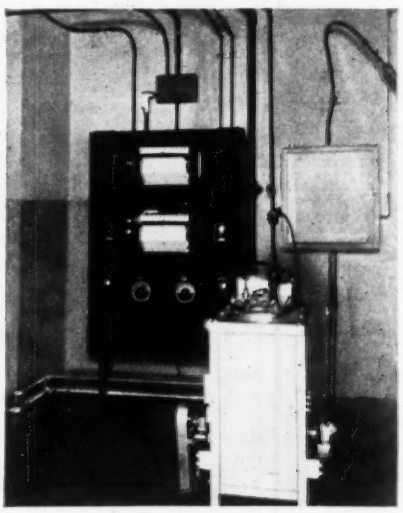
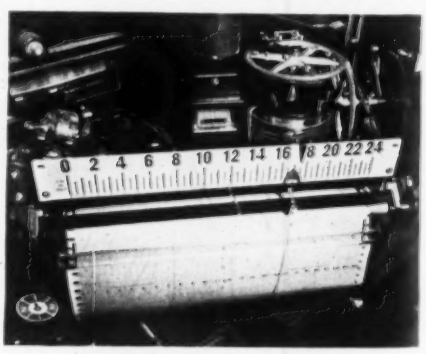
JONES MOTROLA SALES CO.
438 Fairfield Ave., Stamford, Conn.

Process Program Controller

A completely flexible program control system, using maker's potentiometer controllers, is announced. New system is said to provide completely automatic control of such heat treating processes as annealing, normalizing, carburizing and stress relieving, requiring a peculiar combination of equipment all incorporated in an automatic system. Basic instrument is a potentiometer



type controller, and is usually a single-point indicating or recording pyrometer although it also is possible to use the two- or three-record controllers, controlling at the same temperature. In order to accomplish a certain program of temperature control, the control index of the potentiometer type controller is moved automatically from one point to another, either upscale or downscale, by a reversible control-point drive motor mounted in the instrument. Coasting

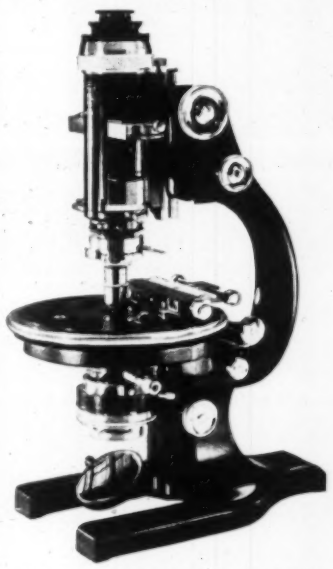


of motor when winding is de-energized has been minimized. It being impractical to supply a different special speed motor drive for each heating and cooling rate, an adjustable current-interrupting device is connected in series with each motor winding so that the speed of control index movement may be varied at will. This interrupter is set by adjusting a pointer on a dial so that the current will flow to the drive motor for a pre-determined percentage of the time. When it is desired to hold a temperature for a certain number of hours without any movement of the control index, this may be

omplished by using a timer, which breaks current to both windings of the control- nt drive motor. (Control index then re- ins stationary until one of the drive mo- windings is again energized.) The timer y be set for any period in minutes or urs, depending upon range selected. It is id that new program control systems are daptable to nearly any control sequence esired, are easily adjusted, have no cams to cut, will not produce false chart records, nd can control multiple-zone furnaces from ne master program.—*The Brown Instrument Co., Wayne and Roberts Avenues, Philadelphia, Pa.*

Polarizing Microscopes

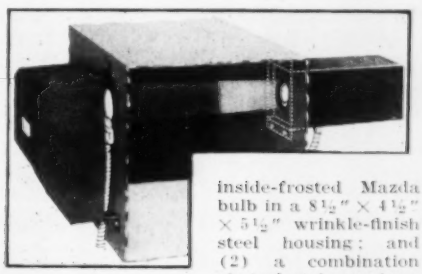
New series of polarizing microscopes comprises six models ranging from the usual chemical microscopes to the large research instruments for petrography, one of which



(No. 37) is illustrated. All are larger and heavier than past Spencer designs and have new refinements for facilitating observation and measurement of optical phenomena as exhibited by various microscopic materials under the influence of polarized light. They are used in the analysis of crystalline materials or liquids that can be crystallized by evaporating a drop on a microscope slide and non-crystalline, anisotropic materials, such as starches and fibers. Fields of application include petrography, mining, medicine, ceramics, petroleum geology, paper & textile analysis, food & drug mfg. The more complete microscopes have Ahrens prisms for polarizing light; these are made of three wedges of calcite so cut and assembled as to give plane polarized light and maintain a large field of view.—*Spencer Lens Co., Buffalo, N. Y.*

Photoelectric Smoke Meter; Combustion Control

Two photoelectric smoke control systems, one manual and one automatic, are announced: *"Model SC-301"* comprises (1) a projector (shown at right) using a standard



inside-frosted Mazda bulb in a $8\frac{1}{2}$" × $4\frac{1}{2}$" × $5\frac{1}{2}$" wrinkle-finish steel housing; and (2) a combination photoelectric receiver, smoke-density indicator and alarm-actuating relay which may be adjusted for smoke density in the breeching. *"Model SC-302"* Automatic Controller comprises the same two main units but its receiver unit (illustrated below) is an automatic controller operating a magnetic solenoid valve for supplying steam and air for over-fire injection; or, automatic control for pressure blower for injection of over-fire air only. Adjustable

time delay on load circuit (20 to 45 seconds) permits correct setting for individual boiler conditions to secure a "smokeless fire regardless of type or quality of fuel used." It is claimed also that this system may permit use of a cheaper grade fuel without loss of boiler efficiency and effect a reduction in fuel cost up to 20% annually. Both systems operate on 110-120-volt direct or 60-cycle current.—*Rehtron Corp., 2159 Magnolia Ave., Chicago, Ill.*

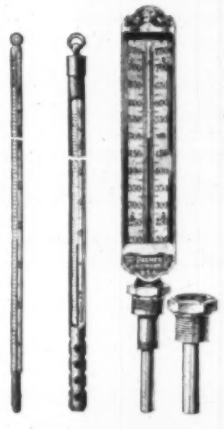
Dynamic Balancing Equipment

New portable dynamic balancing equipment facilitates correction of unbalance of turbines, generators, or other rotating elements. It consists of three principal parts:

a sine-wave alternator, a vibration velocity unit, and an indicating unit and its associated circuits, all fitted in a carrying case. It may be used during initial manufacture or installation of a rotor; after subsequent servicing; or to correct unbalance caused by pitting or corrosion. Rotors may be checked with the device while running in their own or in substitute bearings.—*General Electric Co., Schenectady, N. Y.*

GUARANTEED PERMANENT ACCURACY

is "Built-in" Palmer Thermometers by these 5 separate steps



1. Careful selection of the right type of Palmer "Red-Reading-Mercury" glass for tubes.
2. All tubes are heat treated and high range tubes electrically annealed.
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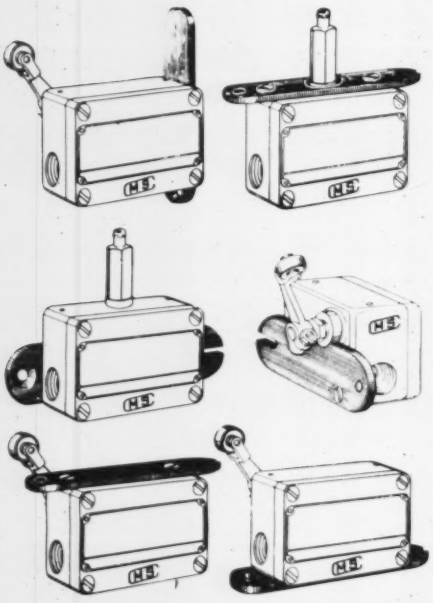
"Acrosnap Switch" is first offering of a new company, employs a new principle whereby positive make and break is said to be produced by a minimum of change in

operating pressure and with minimum movement of actuating pin. Phantom view (upper part of illustration) reveals that new device has the least number of working parts that a snap switch can have: a one-piece blade and no knife edge. This new design minimizes friction and eliminates dead point in operation. Announcement reports "switches as good as new after millions of operations, due largely to the almost total absence of friction." Dimensions, $1\frac{13}{32}$" × $\frac{13}{16}$" × $\frac{33}{32}$"; weight, less than 1 oz. A-c. ratings 10 amps. @ 115 volts to 2 amps. @ 600 volts. Single-pole with normally-open, normally-closed or double-throw contact arrangements. Actuators of various types (plunger, roller, etc.) can be furnished, plain or with reset buttons. "Custom" models of switches and actuators are available. "Special" models having modified electrical and mechanical characteristics can be furnished.—*Acro Electric Co., 3180 Fulton Road, Cleveland, Ohio.*

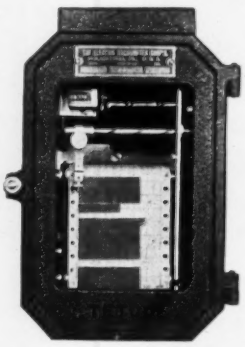
Splash-proof Micro Switch

New splash-proof malleable-housed Micro Switch can be conveniently mounted from any one of four sides for use as an interlock, limit, or pushbutton switch. Two tapped holes for No. 10-32 screws on each of



four sides permit mounting switch directly to a machine frame from practically any position whether the switch has the roller arm, cross-roller arm, or push-rod plunger type of actuation. If lug or foot mounting is desired, 3/16" thick steel mounting brackets can be furnished. Switching element is Bakelite Micro Switch. Assembly is Underwriters' listed and the switching element alone is also listed by Underwriters' at 600 watts up to 600 volts a.c. Both types of roller arm are of aluminum, adjustable through 360°. The roller, of a non-sparking material, rides on an oilless-bronze bearing. Overtravel on this switch is 90°. Plunger type of actuator has a bullet-nose pushrod of case-hardened steel which moves in a long cadmium-plated hexagonal bushing.—*Micro Switch Corp., Freeport, Ill.*

TETCO
Speed Recorder



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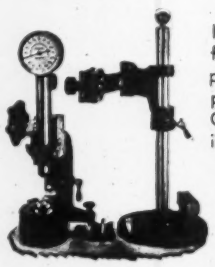

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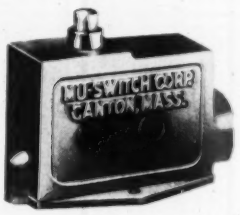
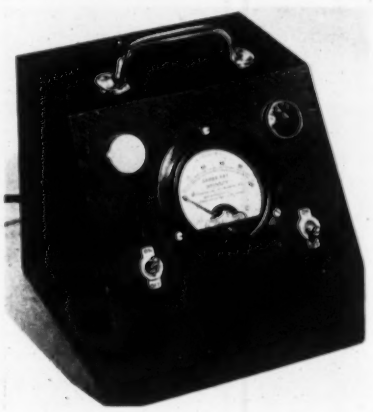
D-c. Switch in Conduit Style Case

To permit its installation in conduit wiring systems, 2-kw. "Type D" Mu-Switch is now available in a cast metal housing $1\frac{1}{2}$" × $2\frac{3}{4}$" × $3\frac{1}{2}$" over-all. For industrial and machine tool applications, the housing is of bronze with hub tapped for $\frac{1}{2}$" pipe thread; for aircraft application, an aluminum case is used with male $\frac{3}{4}$"—20 thread, others to specification. Removable base, with two mounting holes on $1\frac{1}{2}$" centers, gives access to binding screw terminals. An important feature is built-in blow-out magnet which quickly quenches the d-c. arc, prolonging contact life and obviating need for condensers or other external contact-protecting devices. Illustration shows "Style DAP" with compression plunger over-travel mechanism capable of absorbing 5/16" overtravel. Other types of actuating mechanism for Style DAP Mu-Switch include leaf spring, roller, and short-travel plunger.—*Mu-Switch Corp., Canton, Mass.*



Ray Dosage Meter

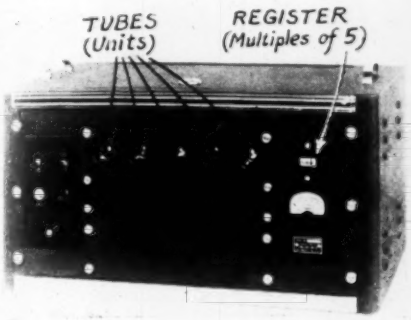
New "No. 163" Dosage Meter serves primarily as a safety device for workers using radium luminous materials and other radioactive materials or exposed to penetrating



X-rays. It is portable and entirely automatic. The gamma-ray intensity is indicated at all times; and a red light is flashed and a buzzer sounded when the intensity exceeds a safe value. Instrument may be used for locating mislaid radium; also for comparing the strengths of radioactive compounds. Its design follows that originally developed for the National Bureau of Standards. It employs a Geiger-Muller counter tube and a vacuum-tube circuit which integrates the pulses from the counter tube and continuously indicates the integrated average. The instrument is non-directional. A built-in voltage regulator compensates for fluctuations in the a-c. supply.—*Geophysical Instrument Co., 1315 Half St., S.E., Washington, D. C.*

2000-per-minute Counter

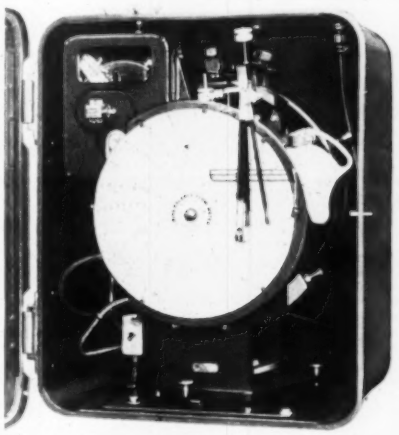
Numbered wheels and other mechanical parts having definite speed limitations, new "High Speed Electronic Counter" employs a circuit which advances the register once for



every five (or ten or more) primary impulses—as is done in other high-speed counters—but in addition it indicates the units by the successive firing of gas-filled glow tubes. The standard "scale-of-5" model (illustrated) has five tubes and at the end of a run the count is obtained by reading the register and adding the serial number of the tube which remains lighted. This "scale-of-5" model has a safe limit of 2000 counts per minute. "Scale-of-10" models and other high-multiple models are available. In all models, the primary impulses are normally, obtained by a feather-touch s-p, s-t, switch, but contactless (photoelectric, capacitive, inductive, etc.) means of actuation can be employed.—*Shallcross Mfg. Co., Collingdale, Pa.*

Combination Flow, Pressure and Temperature Recorder

Added to new line of flow instruments (see *Instruments*, July 1941, page 195) are two meters: "*Model 656*" Recording and Integrating Flowmeter with Pressure and



Temperature Pens, for steam, water, high-pressure gas or other applications with line pressure up to 600 lbs./in.^{2}. Full-scale flow-rate reading is available with any differential head range from 20 to 150 inches of water. "*Model 256*" is similar except that it is low-range; full-scale with any head from 1" to 8" water and 20-lb. max. line pressure. In both models the pressure and temperature elements and flowmeter mechanisms are so arranged that the complete assembly can be swung to make all parts accessible. Both have 12" charts. Both have integrator and recorder driven by a single electric clock of voltage and frequency as specified. The range of any meter can be changed without taking it out of service.—*Ring Balance Instrument Co., 740 N. Franklin St., Chicago, Ill.*

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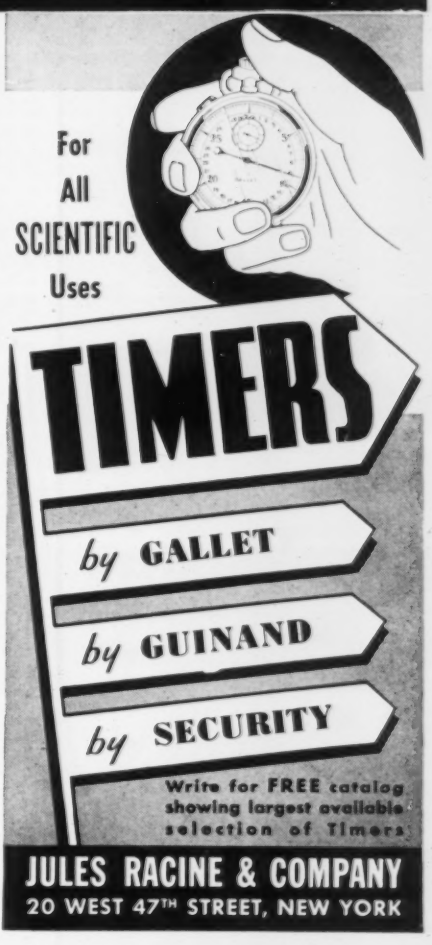
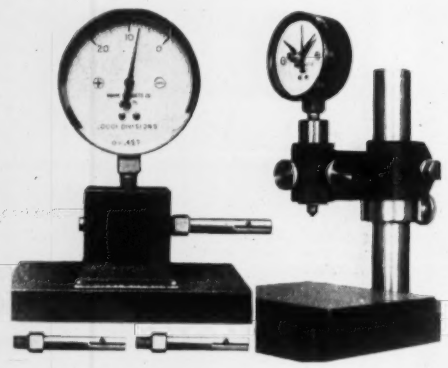


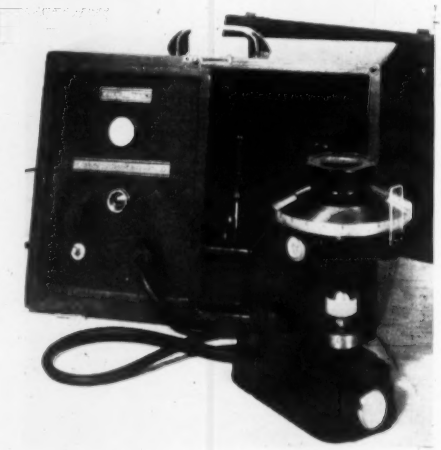
Pneumatic Comparator Gages

Announcement is made of a series of comparator gages (two of which are illustrated) employing a pneumatic method of amplifying small dimensional differences and instantly showing them on a dial type indicator. Pneumatic method is particularly suited to production gaging because wear factor is eliminated and because operator does not depend on his sense of "feel." The measuring points, which are actually air nozzles, do not touch the piece being gaged and consequently cannot wear. Externally adjustable limit pointers (see right-hand view) are provided when speed of inspection is important. In operation, a restricted amount of air from a filtered and regulated supply is admitted to the dial gage and measuring nozzle. Variations in size of the workpiece change clearance from nozzle, permitting more or less air to escape from the nozzle, thereby changing the pressure and actuating the dial gage. The pressure-regulating equipment supplied is said to insure uninterrupted performance regardless of wide fluctuations in main air supply line. Presence of heavy grease or loose dirt on the piece has no effect on the readings since the high-pressure air instantly cleans the surface, it is said. Internal bore gaging, especially for small holes and long tubes, is said to be simple: the plug is merely a guide; the measuring nozzles are recessed below the surface; and the plug itself is provided with ample clearance over the minimum tolerance so that it fits loosely in the bore. The two nozzles are diametrically opposite to measure true diameter and compensate for side motion of plug. A 90° rotation measures "out-of-round" and a lengthwise motion measures taper and "bell-mouthed" conditions. Standard ring gages, representing the tolerance limits, are slipped on the plug at periodic intervals for an absolute comparison, thus eliminating the clearance difficulties of "go" and "no go" methods. Magnification can be made to suit the tolerance measurements, with 0.001" indicated by 2" or more pointer movement. Dimensions can be read within less than 1/32" of edge of workpiece. For external gaging, a single nozzle makes the measurements from a hardened and ground surface plate. Range of adjustments for various size parts and depth of throat are made to suit specific requirements. Where it is desired to record the actual measurement, a round-chart recorder (not shown) is used instead of the indicating dial. Typical applications: gun tubes, recoil cylinders, etc., where measurements are made for each inch of length and where the Inspector keeps a permanent record—*Moore Products Co., 3629 N. Lawrence St., Philadelphia, Pa.*



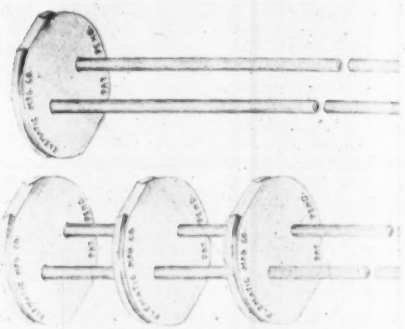
Micrometer for Rubber and Soft Materials

By elimination of contact pressure in measuring thickness, new Carson Rubber Micrometer measures compressible materials as accurately as a shop micrometer measures steel parts. When the tip of its micrometer head is brought into contact with a metallic rider resting upon the workpiece, instant of contact is indicated by a green light before pressure is exerted on the workpiece. This is made possible by an electronic circuit utilizing what is said to be a new "currentless contact" principle sensitive to displacements as small as five millionths of an inch. Instrument is available with a variety of special fittings and attachments for specific measuring problems on various materials. Two standard dials are available: 2½" diam., 0.0001" divisions; and 4½" diam. with "half a tenth" (0.00005") divisions. This larger dial has a vernier permitting reading to a fraction of a division. Complete instrument with attachments is stored in a compartment in cabinet containing electronic unit and control panel. Equipment is portable, operates from 110-volt 60-cycle current supply. Attachments can be supplied to produce unit measuring pressures specified in ASTM standards, or any measuring pressure from 10 mg. as desired. The attachment illustrated for testing rubber thickness provides sufficient weight to hold the specimen flat against the table without appreciably compressing the section being measured, under its 5/16" diam. face.. The same attachment gives precision readings on thin tissue, paper, textiles, fabrics or flexible sheet materials, readily repeating and accurate to twenty-five millionths of an inch.—*Instrument Specialties Co., Little Falls, N. J.*



Thermocouple Wire and Disk Assemblies

Minimized thermal lag, longer wire life, and other practical advantages are attained, it is said, by using the new "Elematic Assembled Thermocouple Wires with Collector Disks." Inside a protecting tube the advantages of the new construction (see illustration) are obvious; but it is claimed also that this construction lengthens the life of unprotected couples in various atmosphere by making the measuring junction the strongest point instead of the weakest. Thermocouple life is increased because the wires, instead of being weakened by twisting and welding to form the usual bead, are joined to the disk by a process which is selected for each pair of standard commercial thermoelements: mechanical compression, gas welding, spot welding, etc. The material of the disk for each standard pair of thermoelements, likewise, is said to be the result of research with the result that the new assembled thermocouples can be used under conditions more severe than those against which the users of ordinary thermocouples are warned. Lower part of illustration shows how the junction disk proper can be supplemented by additional disks: number and spacing as desired. This scheme is particularly desirable in automatic control systems where, with conventional couples, the "dead time" effect of lag produces a "dead zone" in an otherwise sensitive control instrument. In addition to resisting influences that ordinarily cause hot-junction failures, and minimizing thermal lag, the new construction is claimed to increase intrinsic accuracy by assuring the constancy of the temperature-emf relation of each pair of standard commercial thermoelements. Standard disk diameters are available to fit "Carboblast" or other makes of protecting tubes having inside diameters from ¼" to 1½". Various arrangements of disks with bare wire or with porcelain bead insulators are available.—*Elematic Mfg. Co., Instruments Div., Harvey, Ill.*



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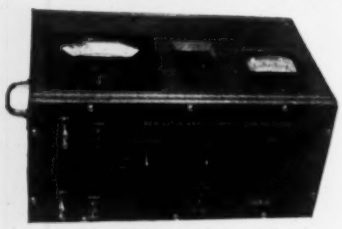

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Plea for New Methods and Instruments in Mechanical Laboratory Instruction

Presented at S.P.E.E. meeting at Univ. of Michigan, Ann Arbor, Mich., July 1941. Printed by permission. See p. 217.

By THOMAS G. ESTEP

Professor of Mechanical Engineering, Carnegie Institute of Technology, Pittsburgh, Pa.

FROM visits made to other Mechanical Engineering Laboratories it is found that there is considerable uniformity in the objectives of laboratory instruction. In general, these objectives are: to become familiar with the various instruments available for making mechanical engineering measurements and to acquire some facility in the use of these instruments; to study various types of machines; to assemble observed and calculated data in an orderly manner; to draw conclusions from such data and finally: to prepare an engineering report on the experiment.

There usually are several different instruments available for mechanical engineering measurements and it is well for the student to become familiar with these various instruments, their accuracy and limitations and to learn to use them to the best advantage.

After graduation, the student will not have an opportunity to study as many different types of machines as will be found in a well-equipped laboratory. The machines he will see and study will be peculiar to the industry which employs him. Many students do not have a clear idea of what type of work they want to engage in and a study of the various machines in the laboratory may arouse interests that will help them in making a decision.

The orderly arrangement of observed and calculated data is absolutely essential for accuracy in the final results and such information is useless unless a critical analysis is made of it and correct conclusions arrived at. To present these analyses and conclusions in a clear and convincing manner in a written report is probably the most difficult part of the experiment.

These are all worthy objectives and it is not the intention of the author that these should be dispensed with. On the contrary, they should be given a great deal of emphasis, particularly in the early laboratory work, but it is felt that in the more advanced courses an effort should be made to show the student what is actually taking place in the machine: from this visual instruction he should have a better understanding of the characteristics of the machine tested.

If a little thought is given to the history of machine and materials testing it will be evident that we have reached a new phase.

Several years ago the engineering college laboratories devised ways and means of mechanical measurements that were accepted by the industry. Since the methods used depended largely upon what instruments were available and the ingenuity of the teaching staff, there was a lack of uniformity in these methods and it was impossible or difficult to make comparisons in the performance of similar machines.

This diversity of method led to the development by the various engineering societies of codes for the testing of machines and materials. These codes have been carefully prepared by experts in their field and give detailed instruction as to the instruments to be used, the method to be employed and the manner in which the calculations are to be made. With these codes at hand, testing becomes routine and requires little imagination or knowledge on the part of the one conducting the test. The job consists essentially in reading thermometers, pressure gages, speed, weights, etc., and little knowledge is obtained of what goes on in the machine.

Perhaps an example will make this point clear. Suppose the problem is to test a centrifugal fan delivering air and to plot the usual quantity, head, power, efficiency curves at constant speed. If this work is to be done in a mechanical laboratory the equipment will be permanently set up with provision made for making all of the various measurements. If the fan is motor-driven it will be necessary to measure the input to the motor. Curves will be furnished with the motor showing the output for a given input. It also will be necessary to measure the fan speed and the air temperature and pressure. The quantity of air delivered will be measured in some approved manner, such as by an orifice or a Pitot tube. These measurements are all simple and the calculations are not difficult because they are all outlined in the test code. The author believes that a high-school graduate could make such a test with no difficulty if he had a copy of the code to guide him.

Assume that the characteristic curves have been plotted and the student is given the task of explaining their shape. To do this he must know what goes on inside the fan.

Suppose that instead of using the usual type of fan, a special fan is constructed in such a manner that the path of the air can be followed through the fan. This could be done by providing windows with special lighting and introducing the proper kind of smoke into the air stream. Then by means of a stroboscope the motion of the air could be studied and for a permanent record a high-speed camera could be used to photograph the air stream. If the student has a good picture of the flow of air through the fan he will have no trouble in explaining the characteristics. The only factor lacking in the picture is the friction and the effect of this is not difficult to visualize.

This is just one example of what could be done in the way of developing new experiments. Some of the research which has been published might easily be converted into regular laboratory work. Such work as was done at Stevens on the flow of steam, or at Westinghouse on accelerated erosion of turbine blades, or the combustion process in internal combustion engines—these and many other problems which have been studied by new methods would be valuable experiments for instructional purposes and are certainly not beyond the ability of senior students to understand.

It is not the author's intention to prepare a list of the newer instruments available and their applications because this would be impossible. The stroboscope and the high-speed camera have already been mentioned. The cathode-ray oscillograph and the many types of electron tubes are so new that their applications to mechanical engineering problems have only been touched. The physicist has made use of many new methods of measurement and study that have opened up entirely new fields but the mechanical engineer has been slow to adapt these new methods to his measurement problems and to provide visual instruction in such a manner that the student will have a clear conception of why a machine has certain characteristics rather than just a knowledge of what those characteristics are. Formal code tests are good training but instruction should go farther.

To develop new methods and applications will require a lot of thought and hard work but the author believes that it must be done. Too much of our laboratory instruction is the same as it was twenty years ago and unless it is kept up to date our graduates will be greatly handicapped in taking their place in research and industry.

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Maintenance and Servicing of Electrical Instruments

By JAMES SPENCER
Westinghouse Elec. & Mfg. Co., Newark, N. J.

DURING the nineteen years that Mr. Spencer has been identified with the Westinghouse Company, his activities have been in the manufacture and test of electrical instruments and relays. During this time his duties were mainly in the instrument line and included assembly test, inspection, field work (application, trouble-shooting and repairing), and time study. At present he is the Foreman in charge of all instrument and relay test at the Newark Instrument and Meter Division of Westinghouse. He has also been engaged in teaching this and other electrical subjects in the Essex County Vocational School of Newark, New Jersey. His teaching experience to date covers about six years. He is still connected with this school.

Mr. Spencer is a graduate of the Newark Technical School in Electrical Engineering. In addition, he has completed courses in Personal Efficiency and Time and Motion Study in the Extension Division of Rutgers University. He has also attended classes and received certificates for teaching in the Vocational Schools of New Jersey.

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CHAPTER I

DIRECT-CURRENT INSTRUMENTS

Electrical measurements involve both the factor of high quality in the instruments and the equally important factor of their intelligent maintenance and use.

Thus the accuracy obtainable is largely in the hands of the user.

Many books have been written on instruments. Some of them are scientific and exhaustive. But none previously printed has been written primarily for the people who have to maintain, calibrate and apply the instruments, in their practical work. It is to this class of reader or student that this series is directed. By devoting a chapter to each type of instrument, the material has been arranged in a simple and consistent manner. The treatment of each type of instrument is the same, so that similarities and differences may readily be noted.

Some of the instruments to be discussed in a practical way as to general theory, construction, test, application and maintenance are as follows: voltmeters, ammeters, wattmeters, frequency meters, power factor meters, synchroscopes, ground detectors, etc. The various principles of operation used in instruments are: permanent-magnet moving-coil, electrodynamic, repulsion, solenoid, moving-iron, Kelvin balance, and electrostatic. Certain of the above types of instruments may be made in both portable and switchboard designs and are made as indicating and recording instruments.

The first instruments to be discussed in this series will be those that measure direct currents only, and have permanent-magnet moving-coil type mechanisms. Permanent-magnet moving-coil instruments are made in both single and double air gap types, both of which will be explained later.

The permanent-magnet moving-coil or so-called d'Arsonval principle is used in ammeters, milliammeters, microammeters, voltmeters, millivoltmeters and in special applications as the mechanism in speed indicators, temperature indicators, galvanometers, ohmmeters, etc. See Fig. 1.

The permanent-magnet moving-coil type instruments measure direct current only, except when used in conjunction with a thermocouple or a rectifying device. This principle is used in switchboard and portable indicating and

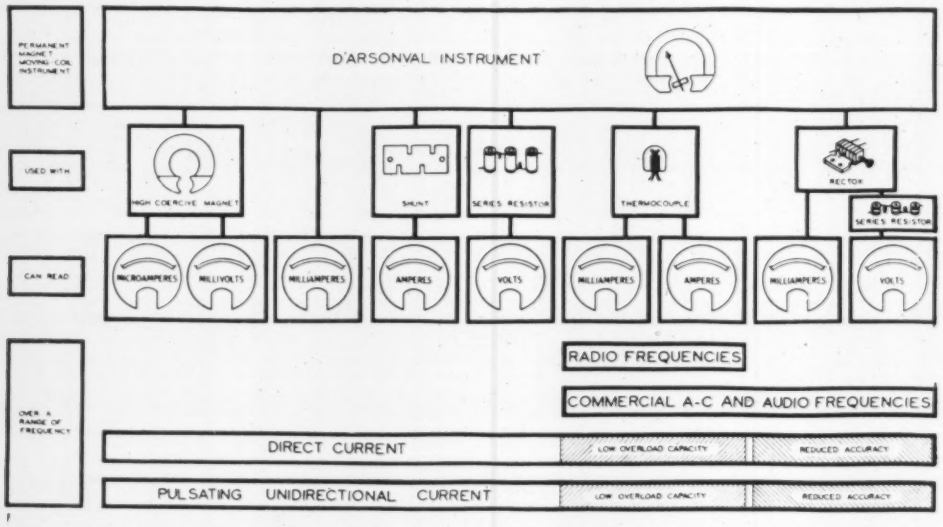


Fig. 1. This chart shows what common accessories are used with the permanent-magnet moving-coil instrument, the purpose of each, and the frequency range in each case. The enclosed wording at the left gives the key to an understanding of the figure. For example: the instrument used without accessories can measure low current up to a few milliamperes, direct current, or pulsating unidirectional current. Used with a thermocouple, it can measure alternating current throughout the radio, commercial, and audio frequencies; low overload capacity.

...ording instruments; and as the galvanometer in bridges ...potentiometers. Essential parts used in the construction ... instruments of this type are shown in Figs. 2 and 2A.

...inciple of Operation:

The operation of the permanent-magnet moving-coil type ...strument depends upon the interaction of flux or lines of ...rce between the permanent magnet and the moving coil. ...he permanent magnet field strength remains constant ...hile the field strength of the moving coil changes with a ...hange in current flow. When a current flows in the moving ...oil a field is set up that tends to line up with the field of the permanent magnet. The turning motion of the moving element produced by the electrical forces is opposed by the mechanical torque exerted by springs. When the electrical and mechanical forces are equal the rotation of the moving element stops, indicating a given value by a pointer attached to the moving element. The damping of this type instrument is electromagnetic. An aluminum bobbin on which the coil is wound rotates in the field of the permanent magnet, causing a voltage to be induced in it. As the bobbin is a closed circuit a current is caused to flow, producing a flux that opposes that of the inducing field, and brings the element to rest with a minimum of oscillations. (The aluminum frame—in effect a short-circuited turn on the moving system—is the conventional damping means but it is not the only one. Other damping means are air vanes, magnetic vanes, damper windings, etc.)

The two controlling springs of this instrument are also used to conduct the current to and from the moving coil. Both the single and double air gap types have pole pieces formed and evenly spaced, to form a circular air gap which gives a uniform field and an even scale distribution. The moving element is balanced in all positions by adjustable balance weights at three points, the tail piece, and two side pieces. Frictional possibilities are reduced to a minimum by the use of hard steel pivots and high-grade sapphire jewels.

A pictorial representation of the above is shown in Fig. 3.

Test and Inspection:

The accuracy of an electrical instrument, and the efficient length of service it renders, are to a large extent dependent upon the care given it in service. For this reason, all instruments should be given periodic inspections and tests if the best results are to be obtained.

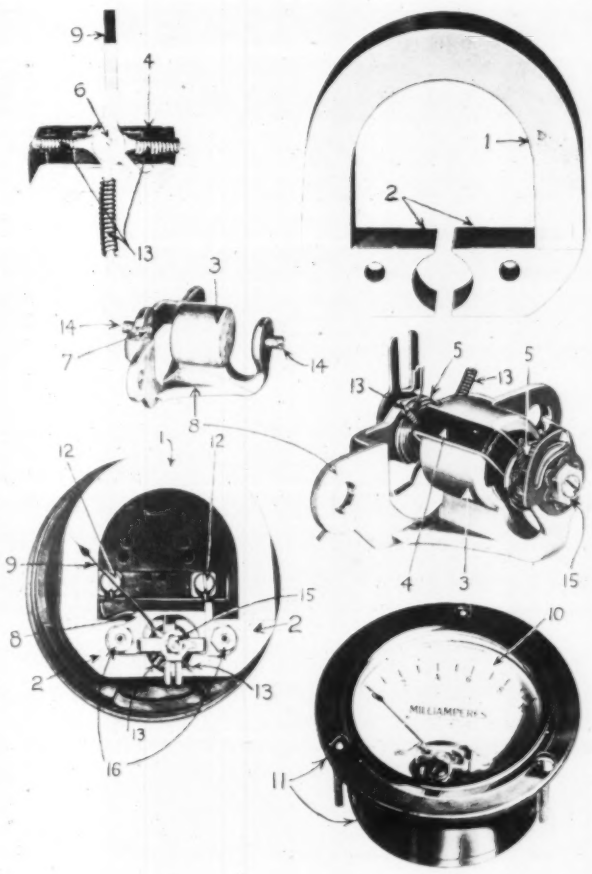
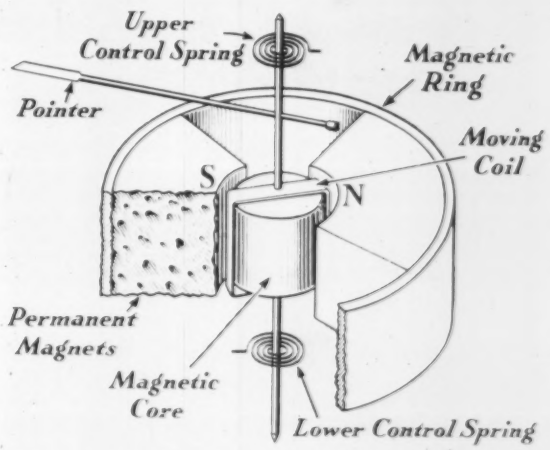
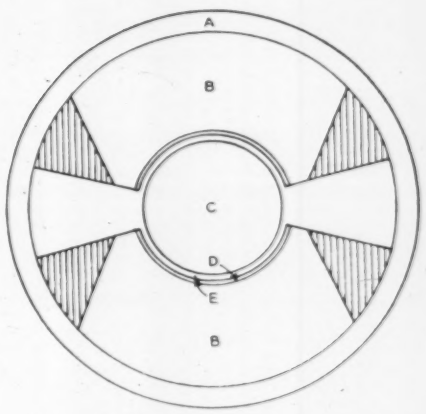


Fig. 2. Essential Parts of a Permanent-magnet Moving-coil Instrument with Horseshoe Form Magnet. (This particular one is a Westinghouse "Type NX.")

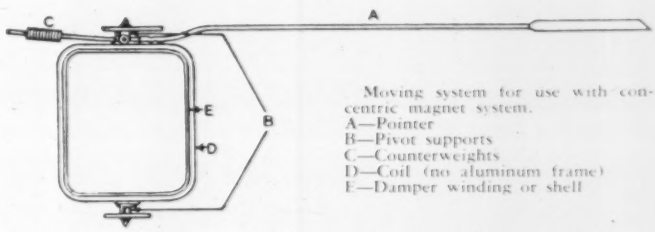
1. Permanent magnet—Horseshoe form, hard steel.
2. Pole-pieces—soft iron attached to poles of magnets.
3. Core—Soft iron mounted between pole-pieces.
4. Moving coil—Aluminum bobbin or self-supporting, wound with enamel-covered copper wire.
5. Control springs—Two phosphor bronze springs, sometimes gold-plated.
6. Pivots—Hard polished steel.
7. Jewels—Generally sapphire.
8. Core plates or core bracket—for positioning core with respect to pole pieces.
9. Pointer—Tubular, flat or channel aluminum.
10. Dial—Zinc, lithographed or paper on metal back plate.
11. Cover and base—Pressed steel or high grade plastics made dust proof with cord, cork or felt gaskets, or some such similar materials.
12. Studs and terminals—Brass, usually nickel-plated.
13. Balance weights—Wire wound or threaded nut type.
14. Jewel bearing holders.
15. Bearing holder lock-nut.
16. Collar type bolts which secure bracket 8 to pole pieces 2.





Concentric - magnet system. Note that the shaded areas are omitted in the actual construction, without sacrificing useful flux, to make instrument lighter and to facilitate magnetization.

A—Soft-steel ring
B—"Alnico" magnets
C—Soft-steel core
D—Thin steel pole-pieces
E—Air gap for moving coil



Moving system for use with concentric magnet system.
A—Pointer
B—Pivot supports
C—Counterweights
D—Coil (no aluminum frame)
E—Damper winding or shell

Fig. 2A. Essential Parts of a Permanent-magnet Moving-coil Instrument with Concentric Form Magnet. (This particular one is a General Electric "Type DB-10.") NOTE—The sketch at the top does not show the exact proportions of the parts; the two drawings, however, are more nearly correct in this regard.

Instrument testing in the field will be considered, first as a general test for instruments mounted on a switchboard and second as a detail test for instruments found defective. The number of times an instrument should be tested in a year depends to a large extent upon the conditions it is subjected to in service. Some of the factors to be considered when planning a schedule for testing instruments are load conditions, location, mounting and accuracy requirements.

Overloading an instrument causes overheating and sudden impact, both of which tend to weaken the various parts of the instrument. Overheating might cause springs to become annealed and lose their tension, coils or coil insulation might be burned causing open circuits or shorts, and connections may become loose causing high contact resistance. Bent pointers and distorted coils are often the result of sudden impacts due to overloads. As the space between the coil and the pole pieces is small, the distortion of the coil often causes it to rub on the pole pieces and cause friction. Bent pointers affect the balance of the element as well as the zero position of the pointer, which in turn affects the calibration of the instrument.

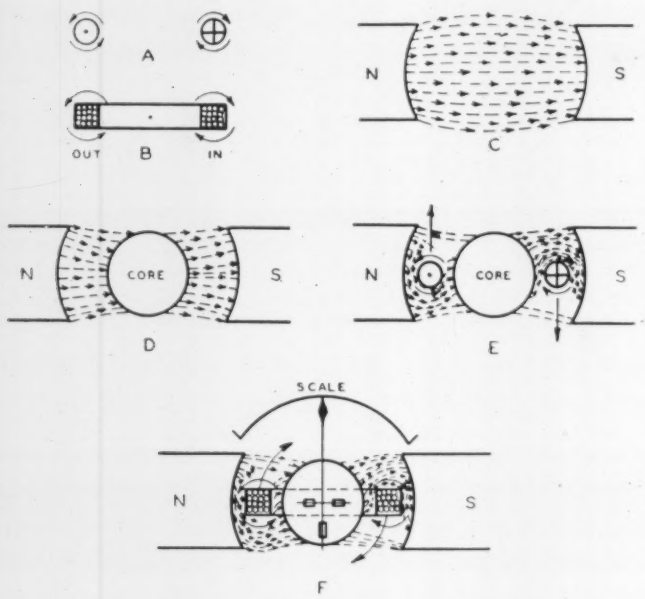


Fig. 3. Two conductors with currents flowing in opposite directions are shown at A. By applying the right-hand rule to the conductor on the left, we have a counter-clockwise field about a conductor whose current is flowing toward the observer. By the same rule we have a clockwise field about the conductor on the right which has a current flowing away from the observer.

B shows the cross-section of a coil with a current flowing in and out as shown. By the same rule as applied to the conductors in A, we have fields about the coil as shown by the arrows.

C shows the lines of force and their direction of flow across the air-gap between the poles of a permanent magnet. The field is not uniform and some of the lines of force tend to leave the area between the poles. With the introduction of a soft iron core as shown in D, the magnetic path is considerably shortened. This shortening of the field increases its permeability, concentrates the lines of force in the effective area and produces a more even distribution of flux.

The effect of placing current-carrying conductors in a magnetic field is shown in E. The conductor on the left has a current flowing toward the observer which produces a counter-clockwise field about the conductor. The field of this conductor opposes the field of the magnet above the conductor and strengthens the field below. Due to this weak field above and the strong field below the conductor, the conductor is forced out of the field in the direction shown by the arrow. By the same reasoning as above, the conductor on the right is forced out of the field in the downward direction as its current flows in the opposite direction to that of the conductor in the left.

F shows the cross-section of a coil in the field of a permanent magnet. With a current flowing through the coil in the directions in and out as shown, a field is produced about the coils as indicated by the arrows. Due to the weakening of the field above the left side of the coil and the strengthening of the field below, the left side of the coil is forced upward as indicated. By similar reasoning the right side of the coil is forced downward as the current, and the field, in and about this side of the coil, are in opposite directions to those of the left side. As the coil is pivoted at both ends, and as the pivots rest is jewel bearing, the coil turns on its axis rather than being forced out of the field. In instruments, the pivot shafts carry the upper and lower springs, and the pointer with its cross arms and balance nuts. When the coil is energized it rotates, deflecting the pointer across the scale. The rotation due to the electrical forces is opposed by the action of the spiral springs, bringing the pointer to rest at a point where the electrical and mechanical torques balance.

In considering the location of instruments as regards setting up a test schedule, there are such factors as moisture, dust, injurious fumes, vibration, effects of stray fields and temperature conditions.

Moisture and injurious fumes cause corrosion, insulation breakdowns, distortion of coils (due to loosening of bonds), open circuits and friction.

Instruments located in places where excessive dust is present in the air should be inspected and tested often as dust and dirt are two of the worst enemies of the electrical instrument. Where extreme cases of the above exist, special care should be given to the dust-proofing of all the instruments used. Dust and dirt cause friction, which accounts for a large percentage of the instrument breakdowns.

Defective pivots or jewels cause friction and hence inaccuracies of calibration. Two of the major causes of defective pivots and jewels are vibration and rough handling. Thus it can readily be seen that if the best results and service are expected with the least test requirements, the instrument should be handled carefully, be protected from shock such as hammering or drilling on the board and should be mounted on a board free from vibration.

Extreme changes in temperature may cause either temporary or permanent effects in the calibration of the instrument. Temporary changes are the results of changes in the resistance of the copper coil or changes of permeability of the magnetic field. Permanent changes are caused by friction due to tightening of pivots in the jewels or magnets being weakened. Because of these temperature changes it is suggested that all testing be done at "normal" temperature: a temperature approximating that of actual use.

Instruments mounted on switchboards should be spaced so that they are not within the effective fields of each other. They should also be out of the effective fields of current carrying conductors. External fields may affect the calibration of the instrument by either temporarily or permanently affecting the strength of the magnet. A fair rule to follow in figuring safe distances between conductors and instruments is by the formula*

$$\sqrt{\frac{\text{(Current in conductor)}}{3}}$$

For example, an instrument would be out of the effective field of a conductor carrying 100 amperes when the distance between the meter and the conductor is $\sqrt{100/3} = 3.33$ inches.

Switchboard Testing:

The test and inspection of an instrument mounted on a switchboard may be satisfactorally covered in the following five steps:

(1) With the current off, check the zero position of the pointer and reset if necessary. Before resetting, however, inspect to be sure the pointer or the element is not sticking, spring convolutions are not touching, and the glass is not statically charged. Element or pointer sticking might be due to foreign materials in the air gap, liat on dial, spring convolutions touching or lack of end play. The glass often becomes statically charged due to rubbing with a cloth. This condition is corrected by blowing your breath on the glass.

(2) Checking connections for tightness is the next step to be made. Loose connections cause resistance changes in the circuit, create heat and cause variable readings. In making this check it is best to kill the circuit to prevent shock or burns. If it is not convenient to kill the circuit, stand on some insulating material and use only one hand whenever possible.

(3) Connect a standard (of higher accuracy than the instrument under test) in the circuit and check the calibration of the instrument under test. If the calibration is in error correct as outlined in the paragraph under "Electrical Adjustment."

*This formula is for unshielded instruments. For shielded instruments a divisor of 6 should be used.

(4) Check the instrument for friction by slowly running the pointer up and down the scale, stopping at intervals and tapping. Friction is noted by a movement of the pointer while tapping or by an uneven movement of the pointer over the scale while checking.

(5) After the first four steps have been satisfactorially completed, the meter should be cleaned and all assembly points checked for dust proof tightness. A few of the points to check for dust prevention are, zero adjuster buttons, case to base assembly, terminal post outlets, loose glass, etc.

Removing from the Board:

When instruments are found defective and it is necessary to remove them from the board, the following procedure should be followed.

(1) Be sure the instrument circuit is dead before disconnecting from the board.

(2) Tag leads and insulate them as a safety precaution and for convenience of reconnecting.

(3) Take instrument to clean work place before opening. Open meter and proceed with repairs.

(4) Microammeter terminals should be shorted when instrument is removed from board, to prevent swinging of pointer causing damage to element.

MECHANICAL AND ELECTRICAL ADJUSTMENTS

Assume that the calibration of an instrument has changed or that a new part has been installed. The test in cases of this kind would be the same as that given a new instrument at the factory.

The instrument is first given a careful visual inspection for clearance of spring convolutions, dirt and filings in the air gap, clearance of coil between core and pole pieces, pointer clearance, and pointer travel above and below scale ends. Air gap inspection and cleaning are greatly simplified by placing a small piece of white paper between the base of the instrument and the element. The paper reflects light through the air gap making foreign particles in the gap more easily detected. A small flash light is a handy tool for air gap inspection. Extreme care should be exercised during the mechanical inspection of the instrument to avoid bending or distorting any part of the element. Bending of parts produces mechanical strains that may change calibration when the stresses are relieved.

End play of the element shaft is next checked and adjusted to have between three to five mils clearance. End play is adjusted by turning the jewel screw in or out until the end to end motion of the pointer shaft is within the

Fig. 4. Instrument shaft with pivoted ends, resting between two sapphire jewels.
A—Shaft with pivoted ends.
B, B—Sapphire jewels.
C + D—Total end play or movement of shaft end to end.
E—Side play, or distance pivot can move from one side of the jewel to the other.

limits stated above. See Fig. 4. Good judgment in estimating end play is important as excessive end play or insufficient end play may cause friction. A convenient method of checking end play while adjusting the jewel screw, is by checking the side play or distance between the angular surfaces of the pivot and jewel. From the diagram, Fig. 4, it will be noted that the side play is several times that of the end play, and therefore may be more easily estimated. The side play can be checked by moving the pointer back and forth in the direction of the pointer length. This adjustment requires extreme care as tightening the jewel against the pivot may cause flat pivots or cracked jewels.

The element is now balanced by adjusting the three balance weights so that the pointer is at zero in the vertical, horizontal and normal operating positions. The instrument should be placed on a table face up and the pointer set on zero before the above balance adjustments are made. To better understand the procedure of balancing, see Figs. 5, 6 and 7.

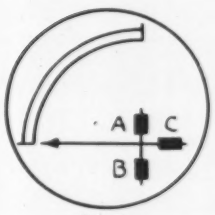


Fig. 5
Horizontal Position. To balance, move tail weight C to the right to make pointer read higher, or to the left for lower.

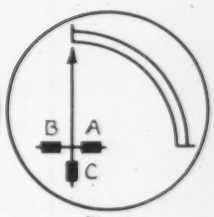


Fig. 6
Vertical position. To balance, move side weights A and B in the direction the pointer should move to be on zero.

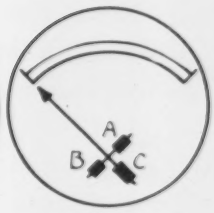


Fig. 7
Normal position. Slight final adjustments of balance in this position may be made by moving the tail weight C.

To check the polarity of the instrument, it is connected to a direct current supply so that current flows from plus to minus in the instrument, in which case the pointer of zero-left and zero-center meters should deflect to the right. In battery-charging instruments under the same conditions, the instrument should indicate discharge.

Before proceeding further with the test, the instrument is given a check for friction. This check is made by applying a full scale current to the instrument and then lowering the current gradually until the pointer comes to rest at or near zero. Due to the rugged construction of switchboard instruments, pivot friction at zero without tapping, may be as much as 0.016". Friction up scale is checked as outlined in paragraph 4 under switchboard testing.

In accordance with the A.I.E.E. requirements, a ground test of 2500 volts for one minute is given standard instruments, while twice the operating voltage plus 1000 volts is given others. The ground test voltage is applied between the terminals and the base or case. Bobbins are usually given an insulation test of about six to eight volts between the winding and the frame.

Calibration adjustments of d'Arsonval instruments are made in any of six ways:

(1) adjusting series resistance,
(2) adjusting swamping resistance,
(3) demagnetizing the permanent magnet,
(4) adjusting the magnetic shunt,
(5) changing spring strength and
(6) adjusting the electrical shunt.

Of the six methods of calibration mentioned, changing the magnet strength and changing spring strength are the only two common to all kinds of d-c. instruments. The method of weakening magnets to obtain calibration should only be used when new magnets are installed as most manufacturers of d'Arsonval instruments demagnetize the magnets 12% to 15% in test as a means of stabilizing the magnet to assure its permanence. Magnets weakened below the 15% point of demagnetization affect the damping, as weaker springs become necessary and the reacting field of the aluminum bobbin is weaker.

The calibration accuracy of large switchboard instruments is generally *one percent of full-scale value*, while miniature type instruments have allowances of two percent of full-scale readings. For zero-center instruments, accuracy limits are doubled if figuring scale lengths as zero center to either end, as all accuracy limits are stated for end-to-end scales.

A clear understanding of the proper internal and external connections of an instrument is essential when making calibration adjustments. In view of this, a diagram of connections for each of the various measuring instruments is given in conjunction with the explanation of calibration adjustments.

Instruments having a small iron bar (magnetic shunt) across the air gap of the magnet may be calibrated with this device. According to the design, the bar is either moved across the air gap or is moved closer to or away from the gap, by a screw adjustment. As the magnetic shunt is moved closer to the air gap or across the magnet, shortening the air gap, it tends to divert a part of the field of the magnet. This diversion of magnetic lines from the useful part of the field of the permanent magnet reduces the torque and causes the indications to be lowered. When in-

struments read low the magnetic shunt is moved in a direction to increase the gap, or it is moved away from the magnet, to make the pointer reading higher.

For instruments not having magnetic shunts, the following electrical adjustments should be made when the instrument requires recalibration.

Voltmeters and Millivoltmeters:

All *voltmeters* (Fig. 8) have series resistance. The resistance may be internal as in low voltage instruments, or it may be external as in higher voltage instruments. To make the instrument read higher, resistance wire is removed to allow more current to flow through the moving coil. Adding resistance wire reduces the current flow to the

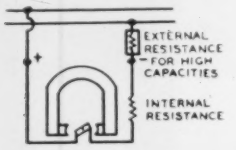


Fig. 8. Voltmeter or millivoltmeter.

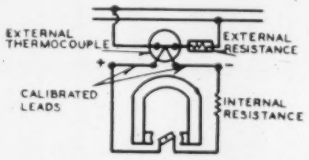


Fig. 9. Thermocouple voltmeter.

moving coil, causing the pointer to indicate lower on the scale. *Thermocouple type voltmeters* (Fig. 9) have a resistance in series with the heater wire of the couple and a swamping resistor from one potential wire of the couple to the moving coil. The resistance in series with the heater wire is adjusted to allow for a flow of current equal to the capacity of the couple, when the full-scale voltage of the instrument is applied. A further adjustment of calibration can be made by changing the resistance in series with the moving coil, changing the millivolt drop across the moving element effecting a change of calibration. *Millivoltmeters* (Fig. 8) are calibrated by adjusting the resistance (always internal) in series with the moving coil, in the same manner as the millivolt circuit of the thermocouple voltmeter. Millivoltmeters should always be used with the leads or a resistance equivalent to the leads used when calibrating the instrument. As the leads are in series with the element, and since the element resistance is relatively low, it can readily be seen that leads of different resistance would affect calibration.

Ammeters and Milliammeters:

Ammeters are made either self-contained or for use with external shunts. Those used with external shunts are really millivoltmeters and should be calibrated accordingly. *Self-contained ammeters* and *milliammeters* (Fig. 10) may be calibrated either by changing the shunt resistance or by adjusting the resistance in series with the moving coil. By

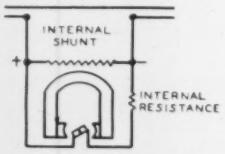


Fig. 10. Self-contained ammeter or milliammeter.

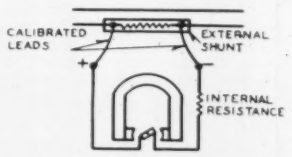


Fig. 11. Ammeter — Millivoltmeter with external shunt.

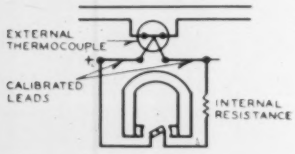


Fig. 12. Thermocouple ammeter.

increasing the resistance of the shunt, more current will flow through the moving coil and hence cause the pointer to indicate higher on the scale. Decreasing the shunt resistance gives the opposite effects. The current in the moving coil may also be increased to give a higher pointer reading by decreasing the resistance in series with the moving coil, and vice-versa. Low reading *milliammeters* have no shunt or series resistance and are calibrated by changing the strength of the magnet. *Radio-frequency type ammeters* and *milliammeters* (Fig. 12) are calibrated by varying the resistance in series with the moving coil or the thermocouple. Instruments used with external thermocouples should be used with calibrated leads.

ACCESSORIES

As noted in Fig. 1, there are four common accessories used with permanent-magnet moving-coil instruments, namely, shunts, series resistors, thermocouples and rectifier units. The first two are used to increase the capacity of instruments while the second two are utilized for the purpose of adapting the permanent-magnet moving-coil instrument for a-c. measurements.

Shunts

Both portable and switchboard shunts are tested by the manufacturer and should give no trouble under normal heating conditions. Abnormal heating due to overload may however cause the solder to melt and allow the shunt plates to loosen or shift, changing the resistance of the shunt. To test for this condition, connect a millivoltmeter of known accuracy across the shunt, after disconnecting the leads of the test meter, and check the mv. drop at rated current. If the mv. drop is low, file the shunt plates until enough material is removed to raise the resistance of the shunt to a point where the mv. drop is correct at rated current. If the mv. drop is high, then the plates should be resoldered or replaced with new plates. A temporary measure, for correcting shunts reading high, is to run solder along the shunt plate and re-test by filing as above. In making shunt tests, be sure that the lead connections of both the shunt and millivoltmeter are tight, as loose connections affect the readings considerably.

Where two shunts are used in parallel to read higher currents, two sets of leads should be used on the instrument, one set for each shunt. In this way, any inaccuracies of the shunts would be averaged, affording the greatest possible accuracy for this test. As the combined resistance of the instrument and leads is small, all shunt tests should be made with the instrument leads supplied to allow for greatest accuracy.

Shunts should always be connected in the grounded side as a safety precaution against personal injury due to high-voltage line conditions that may exist. In general, all switchboard shunts are tested for a 50 millivolt drop across the shunt at its rated current. Standard portable shunts range from 50 mv. to 250 mv. at rated current. Capacities are usually stenciled on the terminal block.

Series Resistors.

Series resistors or multipliers are used with voltmeters to increase the capacity or measurement range of the instrument. Whenever possible, series resistors are connected within the instruments. In high-capacity instruments, however, heating due to the total watt losses within the instrument makes it necessary to connect the resistor externally to reduce the heating.

When a resistor requires attention due to open circuits, short circuits, additional resistances, etc., the following suggestions should be helpful.

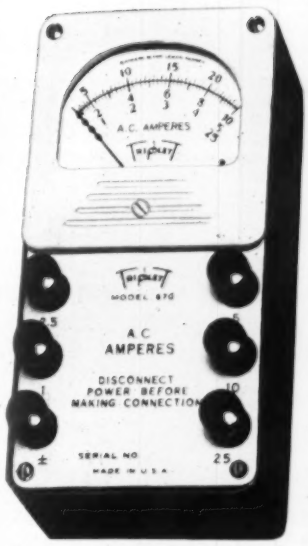
(1) Be sure to use a wire that will carry the full-scale current of the instrument.

(2) Use a wire that has a low temperature coefficient, so as to keep temperature errors of the instrument at a minimum.

(3) Make all connections tight, and if soldered, use a non-acid soldering flux to guard against corrosive effects that may cause open circuits or high resistance paths.

(4) If the instrument reads high and this trouble is traced to the resistor, the error is probably due to a short circuit caused by a break-down of insulation between wires or layers of wires of the resistor units. Some manufacturers short turns of the resistor spools or cards with solder to decrease the resistance when making calibration adjustments. If an instrument reads low, the fault may be due to the solder breaking away from the wire and increasing the active resistance of the multiplier.

(5) If changes are to be made in the range of the instrument, resistance should be added to raise the full-scale



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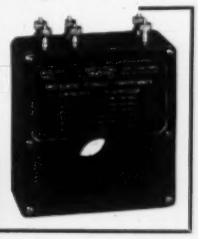

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capacity of the instrument and allow for higher voltage measurements, or resistance should be reduced to lower the full-scale capacity.

Thermocouples and Rectifiers

Both the rectifier unit and the thermocouple are used with permanent-magnet moving-coil instruments for a-c. measurements where low energy only is available. As these units are seldom if ever repaired in the field, it would be of no value at this time to outline procedures on repair. The chief cause of trouble with both these units is overloading. This may cause the thermocouple to burn out or loosen the contact between the potential wire and the heater wire, changing the output of the couple. Overload of rectifier units causes deterioration of the plates, changing the resistance characteristics and hence affecting the output. When in doubt as to the proper application of either of the above units for instrument work, refer to Fig. 1 for details.

Special Uses of the d'Arsonval Principle

Electric Tachometer

The d-c. electric tachometer instrument is a voltmeter marked r.p.m., m.p.h., ft. per sec., cycles per sec., etc. A d-c. magneto or generator is used, whose voltage is proportional to its speed and therefore gives an even scale distribution in the instrument. The magneto is a special type, having a well-aged magnet to assure permanent accuracy, and in some makes the commutator and brushes are made of gold alloy to guard against corrosion or resistance changes. The brush pressure is evenly distributed over the whole bearing surface to prevent sticking at any speed which would cause an error in reading.

In locomotive work, wheel wear changes the calibration; therefore a junction box with differently calibrated resistors or a magnetic shunt is used to make the necessary corrections of calibration.

Electrical Temperature Indicators

Temperature indicators are made in both resistance and thermoelectric types, both of which make use of millivoltmeter indicators; these millivoltmeters being calibrated and marked in degrees Fahrenheit or Centigrade.

Fig. 13 shows a simple resistance-thermometer circuit. It requires a direct-current source of supply for its operation. The indicator is connected across the diagonal of a Wheatstone bridge consisting of a platinum or copper or

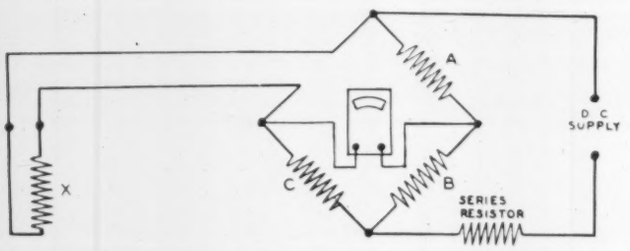

Fig. 13. Simple form of the circuit of a resistance type temperature indicating system: the permanent-magnet moving-coil instrument may be a zero-center galvanometer or a conventional type millivoltmeter.

nickel coil (sometimes called the "thermometer") having a relatively high temperature coefficient, and three Manganin wire resistors having an extremely low temperature coefficient. The thermometric coil is connected to the bridge by copper wires. In many cases, the initial zero of the indicator is set near mid-scale, at the point of normal working temperature of the thermometric coil. The three legs of the bridge, *A*, *B* and *C*, are adjusted so that when the thermometric coil is at its normal working temperature the bridge will be balanced and the indicator will hold its initial zero point. When the temperature is above or below normal, the bridge becomes unbalanced and the pointer deflects to the right or left. The greatest accuracy is had at the point of normal operating temperature, as at this point the bridge is balanced and changes of supply e.m.f. have no effect on the bridge circuit.

The simplest circuit of the thermoelectric type of temperature indicator is shown in Fig. 14. It makes use of a standard millivoltmeter and a thermocouple. The thermocouple consists of a pair of wires of dissimilar metals, joined at *MJ* which is the measuring junction (or "hot junction"

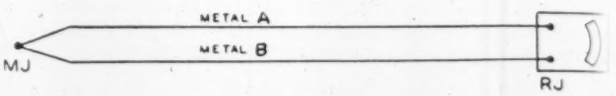

Fig. 14. Simplest form of the circuit of a thermoelectric type temperature indicating system. This simple circuit is found in portable "lance" or "stick" pyrometers. Note that the thermocouple wires themselves are connected directly to the instrument, which embodies a "cold-junction compensator."

These wires may be directly connected to the millivoltmeter bindings posts as shown in Fig. 14, or they may be connected by means of "extension leads" or "compensating leads" as shown in Figs. 15 and 16. In any case, it is the *difference* of temperature between the measuring junction *MJ* and the reference junction *RJ* which generates a millivoltage. Temperature differences between other pairs of dissimilar-metal connections in the circuit likewise generate

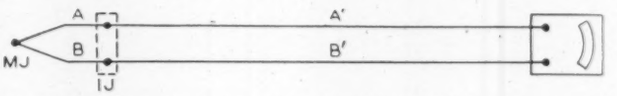

Fig.15. Pyrometer circuit in which "extension leads" or "compensating leads" run from the thermocouple terminal head to the instrument. The terminal head thus becomes an intermediate junction (IJ), really consisting of two junctions, which should always be at the same temperature. The leads A' and B' are frequently of special alloys, selected by the pyrometer manufacturer for use with each particular thermocouple.

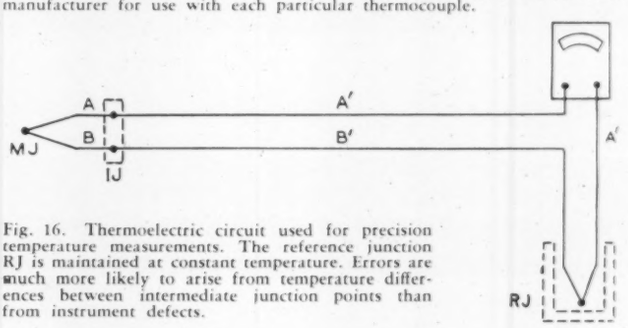

Fig. 16. Thermoelectric circuit used for precision temperature measurements. The reference junction RJ is maintained at constant temperature. Errors are much more likely to arise from temperature differences between intermediate junction points than from instrument defects.

emf's; and such undesired temperature differences (rather than instrument troubles) are the chief source of errors in thermoelectric pyrometry. Another source of error is due to using a thermocouple of a type different from the one used in the temperature calibration of the thermocouple. See Fig. 17. Note that in most applications the available emf. is less than 50 millivolts (and series resistors cut this down further) so that all the instruments are low-range ones.

Another point to note is that millivoltmeters designed for use as thermoelectric pyrometers are generally provided with a built-in "cold junction compensator," usually in the form of a bimetal coil or strip, which corrects for variations in room temperature. This compensator is *not* included in instruments designed to be used in circuits such as the one shown in Fig. 16, where the reference junction is *not* in the

THERMOCOUPLE WIRES POSITIVE NEGATIVE	Millivolts when ref. junc. is at 32°F. and meas. junc. is at: 200°F.	500°F.	1000°F.	1500°F.	2000°F.
Platinum-rhodium (Two types) 90% Pt-10% Rh - Platinum	0.59	1.96	4.59	7.50	10.7
87% Pt-13% Rh - Platinum	0.60	2.01	4.87	8.12	11.7
Chromel - Alumel	3.82	10.6	22.2	33.9	44.9
Iron - Constantan	5.03	14.3	29.7	46.7	
Copper - Constantan	3.97	12.6	29.7		

Fig. 17

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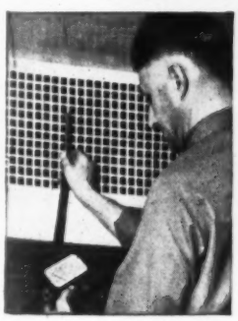

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instrument but in a constant-temperature enclosure (for example an ice-water Thermos bottle).

However, all instruments of temperature indicating systems (whether resistance type or thermoelectric type) embody some form of compensation for the changes in resistance of circuit elements which are caused by changes in room temperature.

Ohmmeters

The ohmmeter (Fig. 18), a resistance measuring instrument of the direct-reading type, is similar in construction to the voltmeter. It is used for quick and convenient resistance measurements where high precision is not expected; also in testing circuits for continuity, shorts, opens, grounds, etc.

A battery or other source of constant voltage is required to operate this instrument. When the terminals of the meter are shorted by the leads, the meter should read full-scale,

Fig. 18

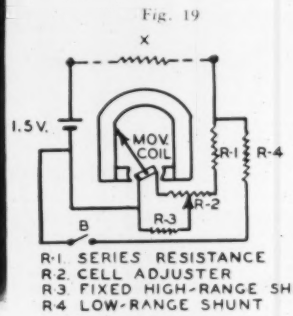


Fig. 19

R-1 SERIES RESISTANCE
R-2 CELL ADJUSTER
R-3 FIXED HIGH-RANGE SHUNT
R-4 LOW-RANGE SHUNT

which is the zero resistance point. When the pointer indicates below or above full scale with the terminals shorted it can be corrected by adjusting the cell adjuster. If a resistance (X, Fig. 19) is placed in the circuit, the current decreases and the instrument indicates some position left of zero. As the scale is marked in ohms, this point being the ohmic value of resistance X. With switch B open and the instrument terminals short-circuited, a current will flow in the circuit. This current will be dependent upon the resistance of the combination of moving coil and its shunt, plus that of R-1 which is a high resistance placed in the circuit to take most of the voltage drop.

When switch B is in the closed position, the instrument reads on the low scale. When the selector switch is on the low range position, a low-resistance shunt is placed across the high-resistance circuit. This shunts a part of the current required to operate the high-resistance circuit. The total circuit resistance then becomes a fraction of the high-resistance circuit and a lower range scale is created.

Insulation Testing Instruments

A well-known and widely-accepted instrument for determining insulation resistance is the "Megger," which is made in a variety of sizes and ratings, the indicating unit in all cases being a permanent-magnet moving-coil ohmmeter. The ohmmeter is mounted in the same portable case with a d-c. generator which supplies the testing current at 500, 1000 or 2500 volts as may be selected. The hand-generator types of the "Megger" insulation tester, as shown in Fig. 20, are the most widely used in electrical maintenance and inspection

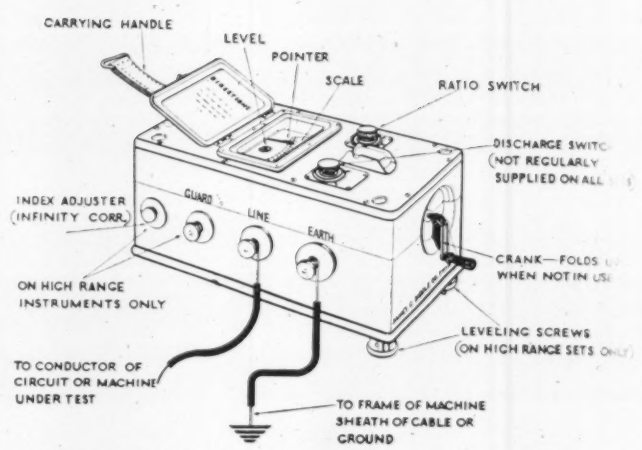


Fig. 20. Showing how to connect and operate a "Megger" Testing Set for testing insulation resistance. Turn the crank at slightly above the speed at which the clutch is felt to slip (about 120 r.p.m.); and—while turning—read the insulation resistance from the deflection of the pointer on the scale.

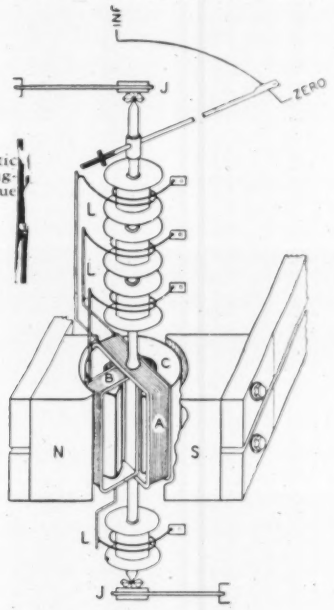


Fig. 21. Showing in diagrammatic form, the moving system and magnet assembly of the "Megger" true ohmmeter.

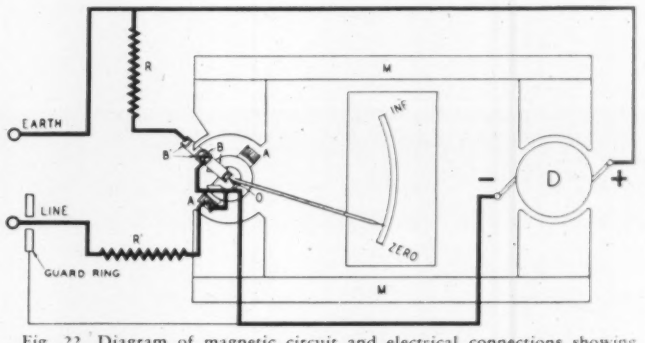


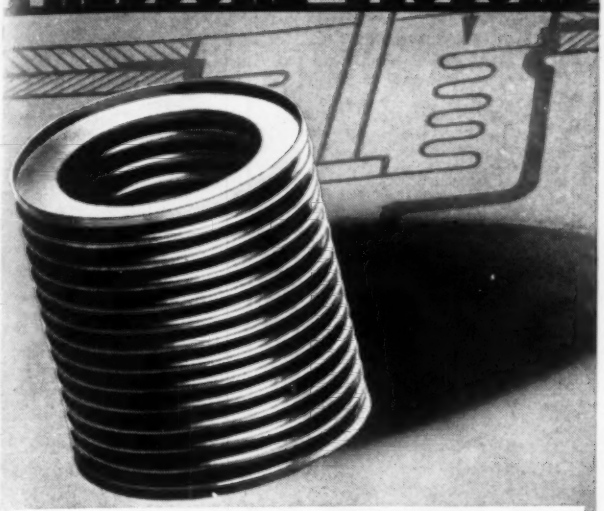
Fig. 22. Diagram of magnetic circuit and electrical connections showing the principle of operation of "Megger" Insulation Testing Instruments.

work, because they do not depend on any external source of power.

Fig. 22 shows the magnetic circuit and electrical connections for all "Megger" insulation testing instruments. The bar magnets M-M serve a dual purpose, as the permanent magnet of the ohmmeter O and as the field magnets of the generator D. The instrument used in the test is a true ohmmeter, capable of measuring resistance independently of fluctuations of the test voltage.

Fig. 21 shows the mechanism of a "Megger" true ohmmeter. The various parts mounted on the pivoted shaft of the moving are, the current and potential coils A and B,

PRESSURE MOTORS



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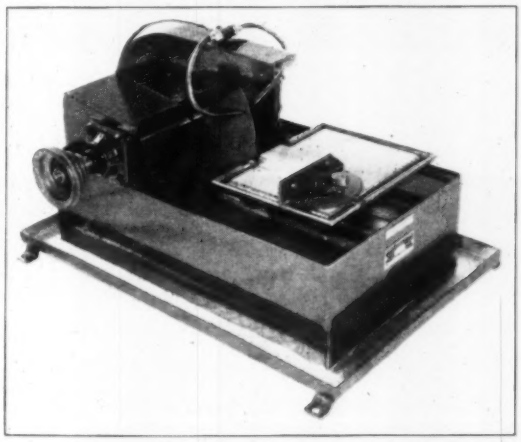

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for insulating bushings around which the lead-in strips *LLL* are wound and the indicating pointer. The stationary parts of the mechanism are the bar permanent magnets *M-M*, soft iron pole pieces *N-S*, soft iron core *C*, the two spring supported jewel bearings and the bracket to which the parts are mounted. The d-c. generator that supplies the test voltage is either the hand crank type as shown in Fig. 20 or is motor-driven.

When a resistance is connected across the ground and line terminals of the instruments, and the generator crank is turned, the ohmmeter will indicate its ohmic value. Since coils *A* and *B*, Fig. 22, are both energized by the d-c. generator, both are affected in the same proportion by any change of voltage and therefore the calibration is unaffected.

As coils *A* and *B* are suspended between jewel bearings and are not affected by restraining springs, the element floats—that is, the pointer assumes any position on the scale when the set is not operated. Coils *A* and *B* operate in the uniform magnetic field of the permanent magnet, and are so connected that they oppose each other electrically.

When an open circuit exists across the line and ground terminals and the set is operated, only coil *B* is energized and it assumes a position opposite the air gap of the C-shaped core. When the coil is in this position, the pointer is at the extreme left side of the dial which is the infinity point. With a resistance across the ground and line terminals, a current flows in both *A* and *B* and the element moves to a position in the magnetic field where the torques of the coils balance. With a different value of resistance across the terminals, the current coil torque changes and the element moves carrying the pointer to a position on the scale indicating its ohmic value of resistance.

MAINTENANCE

The cost of maintaining good, accurate instruments and meters is less than that of just having "fair-hope-they're-accurate" measuring devices. Most of the present-day switchboard and portable instruments are made as nearly perfect as the manufacturer knows how, yet all manufacturers maintain a service department for even the best instrument sometimes requires attention. The accuracy of the instrument, therefore is to a large extent under the control of the user. To impress upon the user that he has this responsibility, the instrument companies send instruction leaflets with their products. This instruction matter sent with the instrument usually gives a great deal of useful information as to the proper methods of handling, placing in service and care.

In power stations, electrical manufacturing plants, electrical repair companies and other agencies where switchboard instruments are used, the instruments should be given periodic inspections and checks. This means that the users should have proper standards for this work or should have the work done by some reliable testing laboratory, or by the manufacturer. If this procedure is followed the life of the instruments will be extended, the plant operation will not suffer due to instrument breakdowns or faults, the products being tested would be more accurate—saving costly field charges and the added confidence and increased pride of the operator using the instruments, would greatly increase the quality of the product and the efficiency of the organization.

Modern instruments are built of materials selected through extensive research. They are properly processed and aged, by highly skilled workmen, therefore, they should give efficient service for many years if given the proper care.

A periodical general inspection for instruments mounted on switchboards would be as follows:

(1) Check all seams such as glass-to-case, case-to-base, terminal outlets and zero adjuster, to be sure they are tight and dust-proof.

(2) Check all connections, especially in millivoltmeters, to be sure of good contact.

Symptom: Instrument Fails to Indicate

POSSIBLE DEFECT	
MECHANICAL	ELECTRICAL
Pointer sticking Bobbin sticking Element out of jewels Pivots tight in jewels	Open element Open series resistor No external circuit Mechanism shorted Open thermocouple Open rectifier

Symptom: Instrument Indicates Incorrectly

POSSIBLE DEFECT	
MECHANICAL	ELECTRICAL
Friction, rolling or static Sticking up scale Spring convolutions touching Off balance Bent pointer Off zero Spring set Spring loose on shaft or holder Loose pointer Loose pivots Loose jewels Pointer does not pass full-scale and zero Wrong end play Warped base Element or dial shift Parallax Pointer vibrating Magnetic dust particles	Poor connection Ground Partial short Wrong connection Magnet weakened Shunt connection broken Temperature error External field effects Static effects (glass) Magnetized pivots Shorted resistor Defective photocell Defective thermocouple Defective thermoelectric circuit Reversed polarity Steel panel mountings Misapplication (AC-DC pulsating)

Fig. 23. Trouble chart for d-c. instruments.

(3) Check instruments for friction by slowly running the pointer from zero to full scale and back, stopping at intervals and tapping meters.

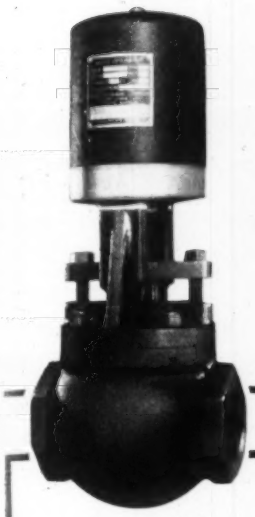
(4) Check calibration against a standard of known accuracy—not necessarily a laboratory standard: a recently-calibrated long-scale instrument will do.

For instruments which appear to be in good operating condition, the above periodical examination and check is sufficient as a precautionary measure. The instruments, however, do occasionally fail in their operation, calling for an investigation of the trouble and its cause. If not given the proper care, however, the possibilities of defects are numerous.

In this discussion we shall cover this subject of defects under the headings of symptoms (or effects), causes, and corrections. Symptoms (or effects) will be treated first for simplicity.

The chart, Fig. 23, gives some of the possibilities and reasons for defects.

From the chart it will be seen that defects come under two general headings, namely electrical and mechanical. Each kind may cause instruments to fail to operate; or to



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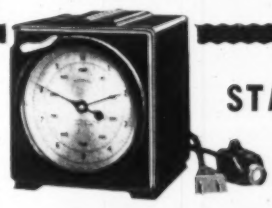

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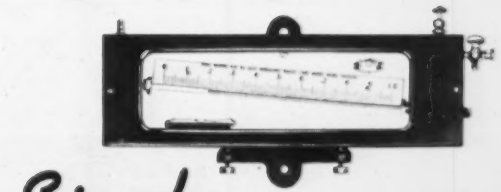
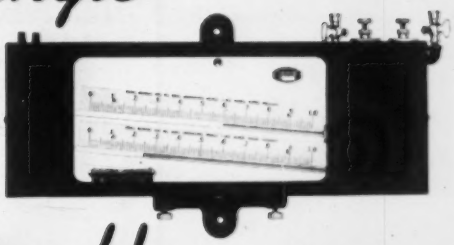


Single



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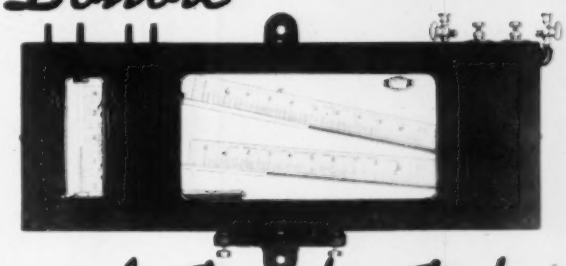

and Triple Tube

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The two tube gauge measures up to 2" of water—is widely used for measuring furnace drafts to secure maximum combustion efficiency. The three tube gauge is similar to the two tube with the addition of a vertical tube—and can be furnished to indicate draft, pressure, balanced draft or differential, on the two inclined tubes, and forced draft on the vertical tube.

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indicate erroneous values. The specific causes listed are those that are most likely. They constitute about 95% of all troubles found by repair men over a long period of time; therefore the chart should be considered a good guide in helping the trouble-shooter.

Friction and open circuits are the chief causes of trouble with electrical instruments. Should it be necessary to dismantle the instrument to correct the faults, several general precautions should be kept in mind. Let us assume that the moving coil of a d'Arsonval type instrument is open-circuited. The *general* procedure in replacing the defective coil should be as follows. (This is a *brief* list: do not act upon it until having studied "Precautions" below.)

(1) Disconnect the instrument from the line and remove from the switchboard.
(2) Clean the exterior of the instrument before opening.
(3) Remove cover and dial.
(4) Unsolder leads to element.
(5) Remove mechanism from base.
(6) Place keeper across magnet.
(7) Remove element from magnet.
(8) Unsolder springs.
(9) Back off jewels screw.
(10) Remove element from bracket.
(11) Unsolder bobbin leads.
(12) Remove springs, pointer, pivots, etc.

In reassembling the meter, the reverse procedure should be followed: (12) *Replace* these parts, (11) *Solder* these leads . . . etc. The careful worker will have arranged the parts in order, so as not to mix them up.

Precautions

When dismantling or reassembling an instrument as outlined, the following important precautions should be carefully observed:

(1) Never hammer, drill or cause vibration on panel board as this may cause friction due to pivots and jewels becoming defective even if not visibly injured.

(2) Clean all around instrument before opening, to prevent foreign matter getting into the mechanism. Sometimes, when an instrument is opened to make a minor adjustment, the pole-pieces which were perfectly clean pick up magnetic dust and the instrument is worse than before.

(3) If instruments are checked on the switchboard, use insulated tools as the pointer, frame, dial, etc., are often a part of the live circuit.

(4) If pivots are defective replace with new ones when possible, as reshaping or excessive polishing may soften the material. (Never grind pivot.)

(5) Loosen jewel screws when working on the element, to guard against pivot or jewel damage.

(6) End play and balance should be carefully adjusted before recalibration adjustments are made.

(7) In adjusting end play, the jewels should be adjusted gradually to prevent flattening the pivots by tightening the jewel against the pivot point.

(8) Care should be taken not to bend or distort spring convolutions, as stresses in the material due to straightening the spring may cause trouble later.

(9) Place soft iron keeper across the poles of the magnet when removing element. This decreases the reluctance of the magnetic path and helps retain the strength of the magnet.

(10) Never use an acid soldering flux when working on instruments, as corroded parts are usually the result. Pure grain alcohol is used by instrument makers for cleaning solder connections.

(11) Remagnetizing a magnet, before first fully demagnetizing it, causes an unstable condition in the magnet, decreasing its efficiency.

(12) Instruments should not be left open too long, as the mechanism may be affected by dust or other foreign matter. Remember that magnetic dust is attracted to the air gaps—the worst place.

Tools and Equipment:

To a large extent, the ease of locating faults and the efficiency of correcting them depend upon the equipment and tools at hand. Therefore let us study for a moment t proper working tools of a good repair man.

(1) A low wattage *test lamp*, to check for opens in t line, meter, series resistors, etc.

(2) A compound *loupe* or magnifying glass should used for checking air gaps of magnets and other such wo

(3) For checking and recalibrating instruments, a s of Grade A *portable* standards should be available as w as a good *ohmmeter* for resistance measurements.

(4) A good instrument tool kit usually includes *at lea three screw drivers:* a pin driver for small work such a dial screws, jewel screws, etc.; a six-inch driver for mediu work; a ten-inch driver for heavy work such as electrica connections, sub-base to base connections, etc. These are th minimum requirement.

(5) *Pliers* for bending, cutting, flattening, and holding operations are essential to an instrument tool kit. The four types found useful are the round-nose, long-nose, side-cutter and large flat pliers.

(6) Every instrument tool kit should have at least two pair of *tweezers:* a sharp steel pair for work on small parts where magnetic attraction will not hinder their effective use and a *phosphor-bronze* pair for work in and around magnets.

(7) A medium-size electric *soldering iron* and a non-acid *soldering flux* are an essential part of the tool kit. The medium-size iron is suggested so as to allow the repair man to make use of one iron for small spring work as well as for large terminal work.

(8) Split type balance wrenches for adjusting balance nuts and a set of small *open-end wrenches* are essential for doing good quality repair work.

(9) A *magnet cleaner* made of a piece of iron wire flattened at one end may be used efficiently for removing iron filings from the air gap. Dirt and fuzz may be removed either by a magnet cleaner, by a feather or by blowing through the air gap.

(10) A pair of small scissors is a handy tool to have for cutting fine wires, springs and other such items.

(11) *Brushes* are handy for dusting off both instruments or parts before opening or closing the instrument case. A two-inch brush is useful for base, case and dial dusting, while a half-inch brush cleans better around the movement and in small spaces.

(12) For measuring the torque of the springs, a set of milligram standard weights and a centimeter scale are helpful.

Repair Parts

Interchangeability of parts in instruments is today one of the features that make possible field repairs without the need of elaborate equipment. This feature allows the user's repair man to stock a few of the parts that are likely to become damaged if the instrument is subjected to abnormal conditions. Having a part on hand such as a magnet, spring, jewel, resistor, etc., has many times saved instrument users much money and inconvenience, due to shut downs while waiting for a part from the manufacturer.

The stocking of parts should not necessarily involve a large inventory if the user of the parts will carefully select the items best fitted to the line of instruments under his control. It is also important that the type of parts be in accordance with the equipment available and the qualifications of the repair man. If the repair man is a competent instrument maker he can keep his inventory low by stocking bare parts such as pivots, springs, jewels, coils, magnets, etc. If he lacks special training in the art of instrument building, he should then stock only sub-assemblies such as elements, mechanisms, etc., that are easily installed by the average mechanic. From the foregoing it can be seen that if proper planning in the stocking of parts is not carefully considered, the repair department will fail to keep the instruments properly serviced, hence the operating costs will be high.

A few suggestions on the stocking of instrument parts are as follows:

MANUFACTURERS' NEW LITERATURE

In this department we report ALL pieces of NEW literature pertaining to Instrumentation, received from the manufacturers. Readers may secure without cost (unless noted) any or all items reported here, by filling out and mailing the card.

I-271 **Pressure Reducing Regulators.** Catalog 70, Bulletin 10, 8½"×11", 8 pages, covers regulators for steam, hot liquids and hot gases—feature is absence of springs and use of compressed air in dome for loading. Foster Engineering Co., 109 Monroe St., Newark, N. J.

I-272 **Automatic pH Control.** Bulletin N-96-709D, 7¾" × 10½", 16 pages, describes and illustrates Micromax control to hold paper stock at specified pH. Leeds & Northrup Co., 4934 Stenton Ave., Philadelphia, Pa.

I-273 **Flowmeters.** Publication 3010, 8½" × 11", 52 pages, covers instrument application to steam, water, air, gas and viscous, volatile and corrosive fluid measurement. Special sections are devoted to control applications, dual range recorders, detached instruments and summation meters. A list of available charts is included. Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.

I-274 **Electric Bond Testers.** Bulletin, 8½" × 11", 4 pages, describes and illustrates Aero-Gun model and Milli-Ohm-Meter model testers. Reference curves or charts are not needed for either model, the measured resistance is read directly from the meter scale. Shallcross Mfg. Co., Collingdale, Pa.

I-275 **Vibration Isolation Chart.** Four-color chart, 17" × 22", shows the percentage of vibration isolation it is possible to obtain in a flexibly mounted assembly with any combination of static deflection and disturbing frequencies. Lord Mfg. Co., 1635 West 12th St., Erie, Pa.

I-276 **Water Gages and Water Boiler Valves.** Bulletin No. 25, 7¾" × 10½", 8 pages, describes and illustrates a number of types of water gages and boiler valves, showing diagrams and dimensions of each. Nathan Mfg. Co., 250 Park Ave., New York City.

I-277 **Per Cent Limit Bridges.** Circular E-50-480(1), 7¾" × 10½", 2 pages, shows limit bridges for inspecting resistors and capacitors used in radios, heaters, telephone equipment and other electrical devices. Leeds & Northrup Co., 4934 Stenton Ave., Philadelphia, Pa.

I-278 **Portable Electrical Testing Instruments.** Bulletin, 7" × 10", 8 pages, covers utility tester for electrical appliances, Model 1220 pocket laboratory tester, dynamometer, channel-analyzer, signal-generator and Model 1280 set tester. Prices of various models given. Superior Instruments Co., 136 Liberty St., New York City.

I-279 **Desuperheater Control System.** Bulletin No. 29-33, 8¾" × 11½", 7 sheets, gives description, characteristics and application data of desuperheat control and includes schematic diagrams of various uses. Brown Instrument Co., Wayne & Roberts Aves., Philadelphia, Pa.

I-280 **"C-D Capacitor."** Vol. 5, No. 4, 16 pages, contains article on coil and condenser testing and a number of brief items on radio servicing. Cornell-Dubilier Electric Corp., New Bedford, Mass.

I-281 **Chlorine Flow Recording.** Catalog. 8½" × 11", 16 pages, describes and illustrates electrical type-E indicating, recording and totalizing chlorine flowmeter and the direct type-M recorder. Wallace & Tiernan Co., Inc., Newark, N. J.

I-282 **Electron Microscope.** Bulletin, 8⅝" × 11⅝", 24 pages, covers electron microscope with magnifications up to 100,000 diameters, describes its operation and shows fields in which it may be applied. RCA Manufacturing Co., Inc., Camden, N. J.

I-283 **Silver Contact Flashers.** Bulletin No. 65, 8½" × 11", 2 pages, describes and illustrates disk motor and unit motor silver contact flashers for 110 volts, 50 or 60 cycle a-c., with the disk motor type limited to 12 circuits and unit motor type for any number of circuits. Reynolds Electric Co., 2650 West Congress St., Chicago, Ill.

I-284 **Air Tools for Aircraft.** Form 2735, 8½" × 11", 16 pages, describes and illustrates riveters, drills, grinders, chippers, hoists, hose couplings and accessories for aircraft manufacture; the fabrication of iron, steel, aluminum and plastic products; tooling up operations, and general machine shop service. Ingersoll-Rand Co., 11 Broadway, New York City.

I-285 **Sound Plugs.** New Catalog Sheet, 8¼" × 10½", 2 pages, covers Types X and XK plugs—straight cord plug, straight cord receptacle, wall plug, wall receptacle and microphone plug. Cannon Electric Development Co., 3209 Humboldt St., Los Angeles, Calif.

I-286 **Dynamic Hardness Tester.** Bulletin, 8½" × 11", 4 pages, describes and illustrates Model No. 7 hardness tester for metals, plastics and industrial materials. Instrument is 4⅛" × 4⅛" × 1¼"; weighs 13 oz. and is furnished in a leather covered case. The R. Y. Ferner Co., 131 State St., Boston, Mass.

I-287 **Photoelectric Products.** Bulletin, 8½" × 11", 4 pages, covers a number of applications of the photoelectric cell, including boiler room smoke alarm, air conditioning smoke alarm, counting devices and burglar alarm. Worner Products Corp., 1019 West Lake St., Chicago, Ill.

I-288 **Transformers.** Catalog No. 400-F, 8½" × 11", 28 pages, describes and illustrates complete line of audio, driver, filament, modulation, plate, power, output and voltage changer transformers; and automatic voltage regulators, chokes and reactors. Thordarson Electric Mfg. Co., 500 West Huron St., Chicago, Ill.

I-289 **General Radio "Experimenter."** July 1941, 8 pages, contains articles on impedance bridges assembled from laboratory parts and a multiplier for the vacuum-tube voltmeter. General Radio Co., 30 State St., Cambridge, Mass.

I-290 **Fractional Horsepower Motors.** Bulletin P-2341, 8½" × 11", 4 pages, describes and illustrates motors with ranges from 1/500th to 1/15th h.p. for a-c. only, for use on fans, unit heaters, space heaters, air conditioning equipment, centrifugal pumps, power pump devices, etc. F. A. Smith Mfg. Co., Inc., North Union at Augusta, Rochester, N. Y.

I-291 **Rheostats and Potentiometers.** Catalog R-61, 8½" × 11", 4 pages, covers heavy duty rheostats and potentiometers for spot welding, mixing panels, motor control, electronic devices, radio transmitters, dynamic voltage control, portable power amplifiers, primary power circuits, electroplating and laboratory work. DeJur-Amsco Corp., Shelton, Conn.

I-292 **"Visaflame" Control System.** Bulletin V-7, 8½" × 11", 8 pages, describes and illustrates control system actuated by light for direct burner mounting for use with intermittent or constant ignition burners. The Mercoid Corp., 4201 Belmont Ave., Chicago, Ill.

I-293 **Optical Clinometer.** Publication No. 889, 6" × 9", 4 pages, describes and illustrates the Cooke optical clinometer intended for general use in toolrooms. Accuracy depends on graduation of a circle and there are no screws, worms or racks concerned with the function of measurement. The R. Y. Ferner Co., 131 State St., Boston, Mass.

I-294 **Control Accessories for Pneumatic Controllers.** Bulletin No. 89-14, 8¾" × 11½", 24 pages, covers valves, diaphragm motor, valve positioner, power cylinder, pressure regulators and filters; discusses air consumption of pneumatic equipment; gives recommendations for selecting air handling equipment. Brown Instrument Co., Wayne & Roberts Aves., Philadelphia, Pa.

I-295 **Rheostats.** Catalog No. 5, 8" × 10½", 8 pages, shows a number of types or rheostats; front or back mounted for application with electric motors, generators, heaters, lamps, filaments, transformers, magnets, arcs, etc. National Electric Controller Co., 5307 Ravenswood Ave., Chicago, Ill.

I-296 **"C-D Capacitor."** Vol. 5, No. 5, 16 pages, contains articles on servicing intermittents and section devoted to radio service hints. Cornell-Dubilier Electric Corp., New Bedford, Mass.

I-297 **Chemical Porcelain.** Bulletins 196, 197 and 198, 8½" × 11", describe and illustrate porcelain for application in process industries—for valves, pipe and fittings and raschig rings. Lapp Insulator Co., Chemical Porcelain Div., 944 Margaret St., Le Roy, N. Y.

I-298 **Radio Equipment.** Catalog, 8½" × 11", 28 pages, covers line of speakers, vibrators, transformers, vitreous enameled resistors, carbon and wire-wound controls, attenuators, plugs, jacks and switches. Utah Radio Products Co., Orleans St. & Institute Place, Chicago, Ill.

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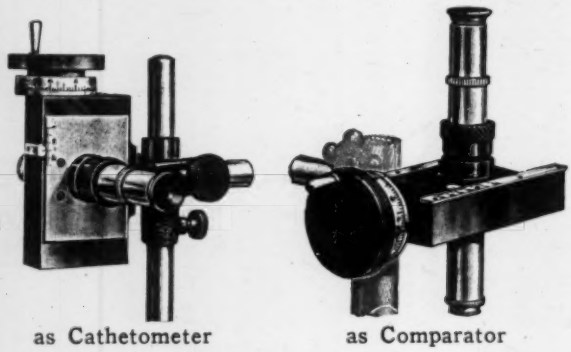

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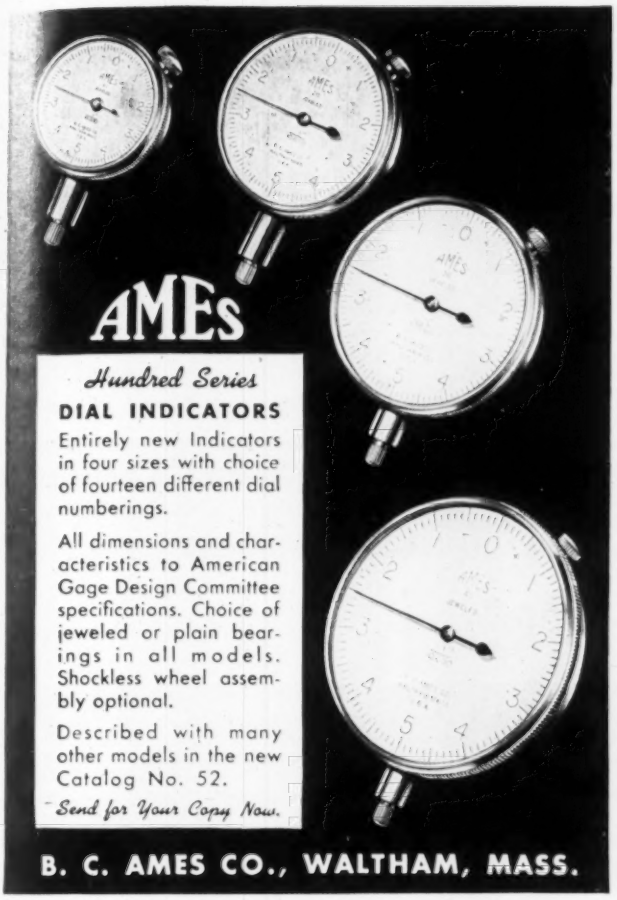
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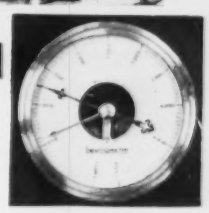

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Magnets should be kept in a clean, dry place and should be about three inches apart to prevent interaction of the magnetic fields from affecting their strength. As magnets are affected by extreme heat, jarring and a-c. fields, they

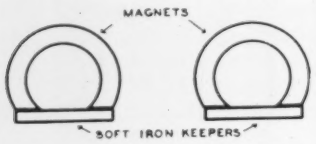

Fig. 24

should not be subjected to these conditions. The poles of the magnets should be closed at all times by soft iron keepers. Wrapping the magnet in paper helps keep the magnet clean and retain its finish. See Fig. 24.

Springs are usually shipped by the manufacturer in small pill boxes with a light packing to keep the springs from jarring and distorting the spring convolutions. Springs should always be stored and handled carefully as distorted spring convolutions require bending to straighten which introduces stresses in the springs causing elastic hysteresis in the instrument.

Pivots are the cause of more frictional troubles in instruments than any other item, therefore extreme care should be exercised in their handling and storing to eliminate breaking or flattening the pivot points. Pivots are usually given a thin coating of oil and wrapped in paper before storing and should be stored in a clean, dry place to prevent rusting due to moisture and dust accumulating on the oil.

Jewels should be given the same care in storing as pivots, as cracked jewels or dirty jewels are also one of the chief causes of friction in instruments.

Moving Elements usually consist of a coil, pivots, springs, and pointers, and should be given the same special care in storing as is given the individual parts. The elements should be kept in a dust-proof container, blocked in such a manner that the element will not shift and damage its parts. Two types of moving elements may be seen in Figs. 2 (middle right) and 2A (bottom).

Mechanisms (see Fig. 25) also require dust-proof containers if best conditions are expected in storing. The mechanism should be attached in the containers so that they will not shift and cause parts to be broken. Since the elements are set and adjusted in the mechanisms as they are in complete instruments, the mechanisms should not be subjected

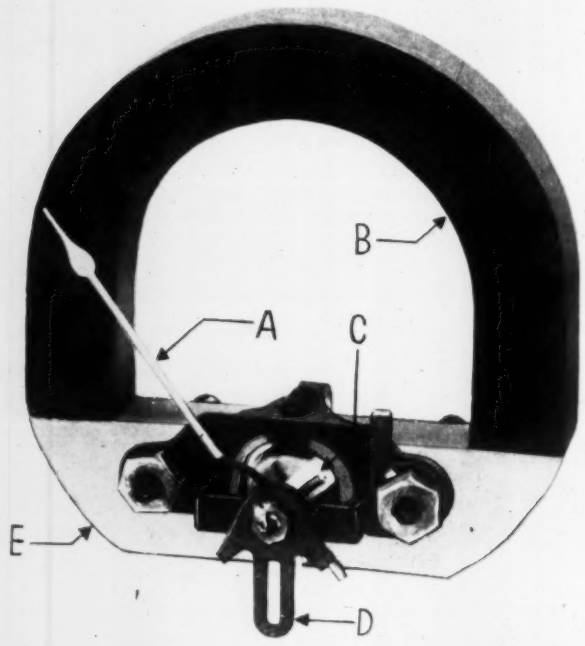

Fig. 25. A complete instrument mechanism. This one is that of the Westinghouse instrument shown in Fig. 2. A—pointer. B—magnet. C—moving coil. D—zero adjuster.

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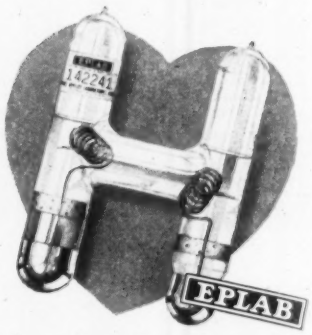

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to abnormal temperatures as expansion of the element may cause pivot and jewel damage.

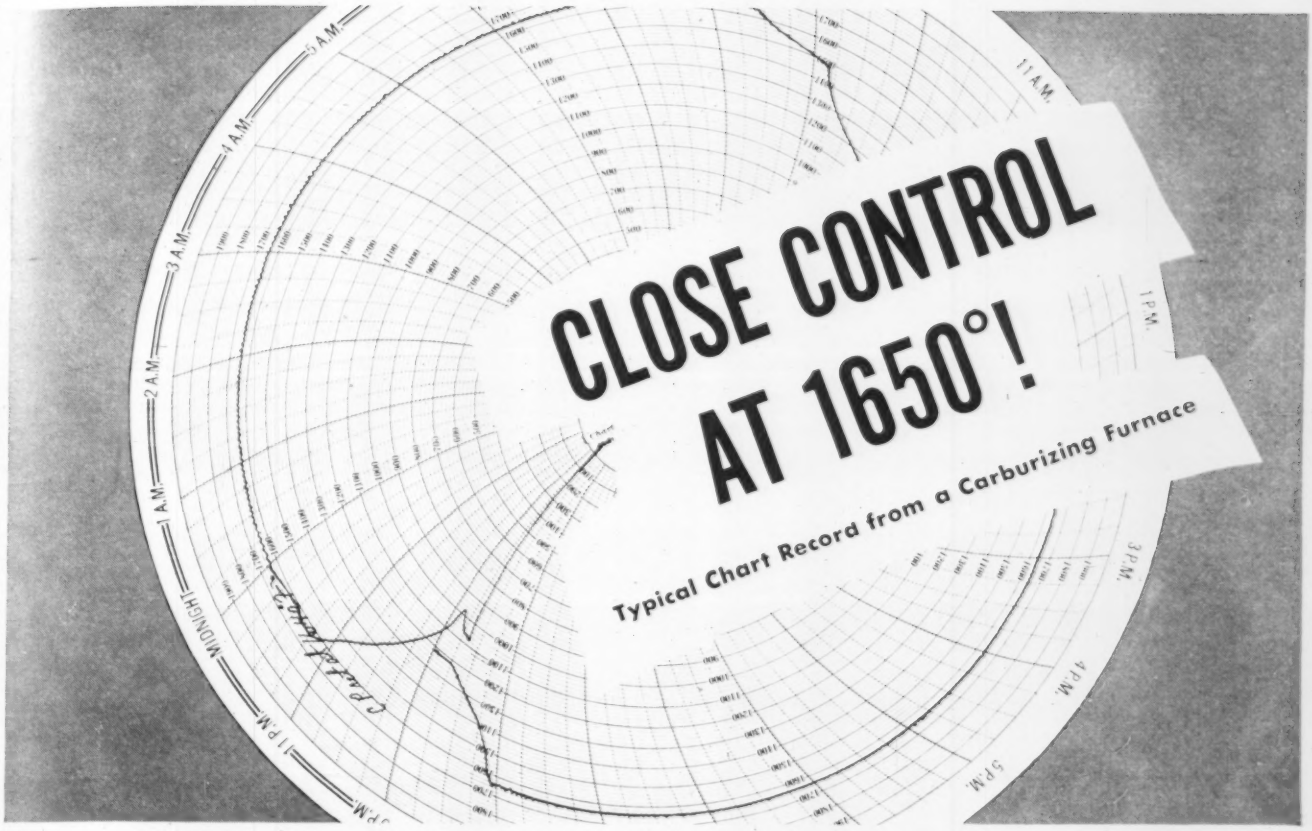
Instrument Thermocouples are made in two types, the bulb and the air type couples. Due to the delicate construction of thermocouples, extreme care should be exercised in handling and storing to prevent breakage. To eliminate the possibility of dirty couples finding their way into instruments, they should be stored in a clean dry place. A dry place is suggested as dampness may have a tendency to rust the potential wires of the couple.

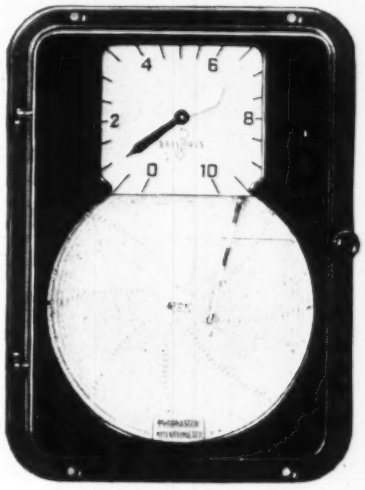
Rectifier Units are made for both internal and external use with instruments. Little trouble is encountered in storing the large external type due to its sturdy construction. The small internal type however is not so permanent and therefore should be given a minimum of handling to prevent disturbing the delicate assembly of the plates and leads. Although the units are properly aged to relieve mechanical stresses, abnormal temperatures may cause the plates to loosen, affecting the output of the unit. The tags attached to the leads of the internal rectifier units should not be removed until used, as these units are usually devoid of polarity markings.

Instrument Dials in general are of three types, paper, lacquer enamel, and silver etched dials. All three types should be kept clean and free of scratches by storing in cellophane bags or inserting a heavy glazed paper between each dial before wrapping. To be sure the dials do not stick to the paper, they should be stored edgewise and should not be subjected to abnormal temperatures. Some white dials have a tendency to turn yellow during storage. These can be bleached white by several hours of sunlight or with an ultraviolet ray lamp.

Should other than the aforementioned instrument parts be kept in stock, it should be borne in mind that clean, dry stocking facilities are the important factors to be considered for the maintenance of quality.

(To be continued)





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7. Easy to inspect or service.
8. Compact for convenient mounting. Lightweight.
9. Round chart an added convenience. Indicating dial if wanted.
10. Surprisingly economical in first cost and operating cost.
11. Supplied also (a) for either air or electric control; (b) in model furnishing two records on the same chart; (c) with an explosion-proof case for hazardous installations.

BRISTOL'S PYROMASTER
POTENTIOMETER PYROMETER